Memoirs of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XXV. No. 1.

UINTACRINUS:

ITS STRUCTURE AND RELATIONS.

BY
FRANK SPRINGER.

WITH EIGHT PLATES.

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The occasion for this paper is the discovery of some remarkable specimens of *Uintacrinus*, which have disclosed a number of entirely new facts, not hitherto suspected, bearing upon its structure and relations. When Mr. F. A. Bather, of the British Museum, brought out his admirable morphological study of this remarkable Cretaceous Crinoid,* it seemed as if he had left but little else for others to say on the subject. This would probably have remained true, but for the accession of fresh material and the discovery of new facts. Mr. Bather has since then prosecuted further researches in Great Britain and on the continent of Europe, with very interesting results bearing upon the occurrence and distribution of the genus in that part of the world.†

He has found that instead of being the rare form in the European Cretaceous which it was supposed to be, evidenced only by the unique specimen described by Professor Schlueter in 1878, *Uintacrinus* is one of the most abundant fossils at the typical locality in Westphalia, although occurring, so far as yet known, almost exclusively in the form of detached calyx plates and brachials. He was, however, so fortunate as to find at Recklinghausen a second well-preserved calyx of *U. westfalicus*, about as good as the type specimen. In England he finds the detached plates very abundant in the *Marsupites* beds of the White Chalk, closely associated with *Bourgueticrinus;* and in some localities west of Margate Dr. Rowe has found them associated with *Marsupites*.

In the meantime the present writer has been seeking for additional

* Proc. Zoöl. Soc. Lond., 1895, pp. 974–1004.

† Geol. Mag. N. S., Decade IV., Vol. III., pp. 443–445, 1896.

knowledge on this side of the Atlantic. From certain peculiarities in the base of some imperfect specimens which came into my possession, I was led to suspect that it might not always be of the form hitherto described. With this question, among others, in view, I undertook to see if further light could not be obtained by a careful examination of the region in western Kansas from which the principal specimens had been derived. In this I was fortunate enough to enlist the interest of Mr. Handel T. Martin, a most intelligent and zealous collector, whose researches have brought to light some of the finest specimens of saurians and birds from the prolific Niobrara Chalk. To his keen eye and skillful hand I am indebted for most valuable aids in the discovery and successful extraction of much of the fine material which rewarded my search.*

DISCOVERY AND COLLECTION.

The first specimen of *Uintacrinus*, too imperfect for description, however, was found in 1870 by Prof. O. C. Marsh in the Uintah Mountains, in northeastern Utah.† In 1875 weathered specimens were discovered by Prof. B. F. Mudge,‡ in Trigo County, Kansas, upon one of which Grinnell § established the genus, and described the typical species, *Uintacrinus socialis*, the specific name referring to the fact "that the individuals of this species lived together in large numbers." Both Marsh and Grinnell allude to a resemblance of this new form to *Marsupites* of the English Chalk.

Some of Mudge's specimens were sent to the Smithsonian Institution, and were described and figured, with his usual discriminating accuracy, by F. B. Meek. ||

None of the foregoing specimens disclosed the nature of the base, which remained unknown until the discovery of a specimen in the *Marsupites* zone near Recklinghausen, in Westphalia, which was elaborately described and figured by Professor Schlueter, in 1878, as *U. westfalicus*. ¶ His description confirmed the opinions of Marsh, Grinnell, and Meek that this Crinoid

* I feel much satisfaction in noting that Mr. Martin has since been appointed Assistant in Palæontology in the Kansas University at Lawrence, whose rich Museum contains many of the finest specimens discovered by him.

† Am. Jour. Sci., March, 1871, p. 195.

‡ Rep. U. S. Geol. Surv. Territories, 1875, p. 284.

§ Am. Jour. Sci., July, 1876, pp. 81–83.

|| Bull. U. S. Geol. and Geogr. Surv. Territories, II., 1876, pp. 375–378.

¶ Zeitschr. d. Deutsch. Geol. Gesel., XXX., pp. 55–63.

was stemless, and showed that the base consisted of one circlet of basals surrounding an undivided pentagon.

In 1893 W. B. Clark * gave a more extended description of *U. socialis*, and made a detailed comparison of the species with *U. westfalicus*.

In 1894 Dr. S. W. Williston and Mr. B. H. Hill † gave an account of some new and much more perfect specimens, found by Mr. E. E. Slosson in Logan County, Kansas. These were the first that had been found in place and unweathered. Williston's account of this discovery is as follows:—

"While all the colonies hitherto discovered have been exposed and more or less weathered, the present one was found in position, covered by a soft blue shale. The animals had lived so closely together that their very long arms had become inextricably entangled, and by consolidation had formed a dense calcareous plate, about one-third of an inch in thickness in the middle of the plate, but thinning out at the margin. . . . The calices all lie flattened out, showing in some cases the basal plates, but, as might be expected, never the upper or ventral portions. The interlacing of the arms prevents the tracing of any to the extremity."

Hill described the base as being constructed of "a small, five-sided, centrodorsal plate, around which are grouped five pentagonal basals;" and he said that the "interradials" were usually seven, and interdistichals two in number. Hill's figure is in some respects incorrect and misleading.

In 1898 Mr. W. N. Logan ‡ published a "revised description" of *U. socialis*, and gave a new figure, which added nothing, however, to the previous knowledge of the genus or species.

In the meantime Mr. Martin found a deposit of very small specimens, most of which were secured for the Kansas University Museum. He also discovered, about the same time, another colony of *Uintacrinus socialis* in place, some of which were acquired by the British Museum, and formed the subject of Mr. Bather's paper of December, 1895, already mentioned. A large slab from this find was also acquired by Prof. O. C. Marsh, for the Yale College Museum, and a description of it was given by Prof. C. E. Beecher, § who found nothing in the specimens to throw new light upon the structure of this Crinoid. All of the specimens of *U. socialis*, except the one from the Uintah Mountains, have thus far been found

* Bull. U. S. Geol. Surv., No. 97, pp. 21–24.

† Kansas University Quarterly, Vol. III., No. 1, pp. 19–21.

‡ Kansas University Geol. Surv., IV., p. 481.

§ Am. Jour. Sci., April, 1900, p. 267.

in Logan and adjacent counties in western Kansas, within a radius of less than twenty miles.

The first result of the search begun by me was the unearthing of an extensive continuation of the deposit in which Mr. Martin found the last mentioned specimens. As this is by far the most important occurrence of these Crinoids ever found, I will first give a somewhat full account of it, and afterwards of the other localities known to me.

Locality No. 1. — This is on the side of a deeply eroded ravine, near the town of Elkader, in Logan County, Kansas. The fossils occur in the upper part of the Niobrara Chalk, at about the junction of the so-called yellow and blue shales. They were in place, covered by a considerable thickness of overlying strata, and constituted the remains of a very large colony. The deposit was in the form of a lenticular mass, upwards of half an inch thick in the middle part, and thinning out on all sides to the thinness of cardboard. It was approximately fifty feet long on the outcrop, and extended into the hill for a maximum distance of about twenty feet. A large part of the plate had been washed away with the erosion of the ravine. It was not at all parts equally productive of good specimens. The layer gained depth very rapidly as it passed into the hill, and a large quantity of stripping had to be done to get at the best part of it. After this about three weeks' time was consumed in the work of taking out and packing the specimens. The entire deposit was exhausted, the layer being followed until it thinned out on all sides. In all upwards of twelve hundred specimens were obtained in which more or less of the calyx is visible. The preservation of the Crinoids from this locality varies considerably. In some parts they and the matrix were almost white; in others, tinged with oxide of iron to a yellowish tint; and in yet others the matrix was a bluish gray or lavender. In the latter the preservation was the best, and the fossils were not so much affected by chemical action. It is strange that within a few feet of these the specimens should be greatly injured by some chemical agency.

The plate containing the Crinoids is of limestone, entirely composed of the comminuted remains of these animals. It rests on a so-called shale, consisting of a rather soft blue or yellowish calcareous mud, and is overlaid by a somewhat similar layer, passing into quite pure yellow chalk above. The shaly appearance is a condition of weathering, and is con-

fined to the outcrop. All of these layers, whatever their color, are chalk, more or less pure, composed of the remains of Foraminifera. The impurities, according to Williston,* vary from less than two to ten per cent.

An account of the microscopical investigation of the Niobrara Chalk, and description of the organisms occurring in it, by Mr. C. E. McClurg, may be found in the Report of the University Geological Survey of Kansas, Vol. IV., p. 415 *et seq.* To the presence of the soft, muddy bottom of a quiet, mediterranean sea, or lagoon, forming this deposit, is due the excellent preservation of the fossil remains. Those Crinoids that were at the time at the lowest part of the floating mass rested directly upon the soft mud, and settled into it, in the position in which they happened to be. They were thus perfectly embedded by the lower side in a fine matrix, which would preserve them like a mould. The others piled on top of them, and not having any such soft or plastic bed to receive and preserve them, were crushed out of shape, disarticulated, and their calyx plates and brachials were indiscriminately mixed up. These were cemented together by pressure, forming the slab — a thin layer of limestone as we now find it — with the Crinoids preserved *only* on its *under side.* These should all be approximately perfect, — except for one fact hereafter explained, — and if they could be taken up with about an inch of the chalky mud adhering, and then have this very carefully removed, most of the specimens on the lower surface would be quite perfect. In practice this is impossible, for the only line on which the layers will separate with any regularity is at the junction of the limestone slab with the chalk, and in many cases those parts of the Crinoids which were deepest embedded in the matrix are pulled off and left in the opposite surface. This almost always involves the finer extremities of the arms, which are so delicate as to preclude recovery out of the matrix. In some cases the parts adhering to the chalk were, by great care and patience, cut out with a block of the matrix and pasted upon the Crinoid from which they had been broken, and then the block of matrix afterwards worked away; but in the case of the fine extremities of arms this could not be managed. Hence it is that we do not ever get the arms preserved to their full length. But enough of them was found to show nearly their full length, and to furnish complete proof of what it must have been in life. The injuring of the specimens by the pulling off of plates and arms has its compensations, however, for

* Univ. Geol. Surv., Kansas, Vol. I., p. 239.

it is by such broken specimens that some of the most important information touching the structure of these Crinoids has been revealed, which would perhaps not have been discovered had all the specimens come out uninjured.

The Crinoids are found in all positions. The majority of them lie on their sides. Many were embedded base downward, leaving that exposed and uppermost upon the slab now. Several were found, fortunately, with the ventral side of the calyx down and buried in the matrix, and these proved to be gems of the first water. The arms are sometimes closely folded, but more often opened out. We do not always see the calyx belonging to a good set of arms, because the calyx was enclosed in the mass of Crinoids, and only the arms happened to be on the lower side of the floating mass so as to be buried and preserved in the soft sea-bottom. So the arms will now seem to run into the hard limestone layer toward some calyx which was crushed out of all shape and cannot be exposed now by removal of surrounding material. So, *vice versa*, a fine, plump calyx which was on the lower outside of the floating colony is shorn of some of its interest as a specimen, because the arms run into the limestone slab, and are lost. Considering that they were all entangled by the arms and pinnules, it is to be expected that specimens fully exposed would be rare. Nevertheless, many splendid specimens were secured, by which we are able to work out the morphology of this interesting Crinoid to a degree of satisfaction rarely, if ever, before obtained in a fossil. One of the finest of the slabs from this colony may now be seen upon the wall near the entrance of the Museum of Comparative Zoölogy at Harvard College. It is about eight feet by four, and contains about one hundred and twenty-five Crinoids, many of them with long arms, and finely preserved.

The walls of the calyx of these Crinoids are thin, and the plates are apparently connected by a sort of articulation, or loose suture. The calyx was very large and light, and without rigidity. All are crushed so that the opposite walls are brought together in the form of a concavo-convex bowl. The superincumbent weight pressed the undermost wall into the soft mud, and the uppermost wall into the concavity thus formed. Specimens that now appear convex and plump upon the inverted surface of the slab have the opposite wall pushed into a concavity equal to the convexity of the outer exposed wall. Occasionally the calyx comes entirely loose from the matrix, and we find the opposite wall in the concave part underneath.

The specimens in this colony are mostly of adult individuals, — the calyx measuring from 37 to 75 mm. wide as it lies crushed; these would have been from 20 to 50 mm. in diameter in life, after allowing for the flattening. A few individuals — not over a dozen in all — were found in the young stage, 15 to 25 mm. wide, representing diameters of 9 to 15 mm.

Locality No. 2. — This was about half a mile from No. 1. Here a small deposit of mostly very small Crinoids was found in place, — about 15 square feet in all. They occurred in a similar manner and position to those of Locality No. 1, and the specimens were entangled in like manner by the arms and pinnules. The specimens originally found by Mr. Martin at this place were mostly disposed of to the Kansas University. By carefully searching the *débris*, as further exposed by flood and wind, I succeeded in finding some fragments of the plate containing a number of individuals. The occurrence of this colony was noticed by Dr. S. W. Williston in the Report of the University Geological Survey of Kansas, Vol. II., p. 242, where he stated that it "may belong to a distinct species, but is more probably the young of socialis."

Locality No. 3. — About twelve miles southeast of No. 1. Here I found the weathered remains of an adult colony which had evidently been of considerable extent, but most of it was destroyed by the erosion of the beds. Fragments of thin slabs, with parts of arms and some calices, were scattered over a space of several hundred feet along the exposure, — the effect of wind and rain, — but at no place in position and unweathered. The weathered specimens found here almost invariably have the arms closely folded together, so that they look like bundles of parallel rods. None of them are spread out, as is so common at Locality No. 1. The preservation of the arms and brachial plates is very fine, especially for showing the syzygies, — both in a lateral view, and upon the apposed surfaces of the brachials. Unfortunately in only a few cases was the base visible, — it being usually either concealed or broken away. At this locality, about three hundred feet from No. 3, there was found in place a small remnant of the thin edge of another colony, from a different horizon, — being apparently about three feet higher than No. 3, — but the Crinoids were in poor condition.

Locality No. 4. — Five miles southwest of No. 1. Fragments only, and the deposit not found in place.

Locality No. 5. — Ten miles northeast of No. 1. Fragmentary remains

of a colony were found here, weathered out. The deposit was not found in place, but small fragments show that it must have been a large one, for some of them belong to a plate half an inch thick, but entirely destroyed by the erosion of the ravine. One fine calyx, with arms partly preserved, was found here, entangled with parts of other individuals as usual.

Locality No. 6. — Two miles northeast of No. 1. This was Professor Slosson's locality, mentioned in Dr. Williston's account in the Kansas University Quarterly, already cited. The description of the occurrence has already been quoted *supra.* The deposit was entirely exhausted, but at a point about one-eighth of a mile distant I found the weathered fragments of what may have been another colony, Locality No. 6 *a,* among which were several fairly good specimens.

Locality No. 7. — Seventeen miles west of No. 1. Fragments with a good calyx and arms were found here some years before, but no deposit *in situ.*

Weathered fragments have been picked up in three or four other spots in the same region, but they may have all been derived from the above mentioned localities, transported a great distance by wind or water.

OCCURRENCE AND DISTRIBUTION.

Having been found in Utah and Kansas, in localities over five hundred miles apart, it is evident that *Uintacrinus socialis* was widely distributed, and its fossil remains may be looked for in America wherever the upper part of the Niobrara Chalk is exposed. Being a free floating Crinoid, it might be expected to have abounded irregularly throughout the great shallow interior-continental sea, in which the chalk bottom was forming.*

Nevertheless, it is somewhat remarkable that so few of them have been found, considering the great extent of the formation and the favorable character of its exposures. The Niobrara Chalk has been searched by organized parties and individual collectors almost every year since the first important discovery of saurian remains in 1870; and ever since Mudge found his weathered specimens of *U. socialis,* in 1875, collectors have been on the lookout for Crinoids. Yet with the exception of a few other fragmentary weathered specimens found by Williston and Cooper, the colonies found by Slosson, Martin, and myself are all that have ever been brought to light. When we consider how wonderfully prolific this formation has

* Dana's Manual of Geology, 4th Ed., p. 826.

been in saurians, fishes, and mollusks, it is hard to understand why the Crinoids are not more abundant, and why they are so limited as to horizon. The *Ostrea congesta* is always found in the same exposures with the Crinoid layer, and mostly below it. This was the case at the original locality in Utah, where the first specimen was found by Marsh. The huge Inoceramid shells of *Haplascapha grandis* are also found a little way below. The Crinoids do not seem always to be confined to the same exact horizon, although they are nearly so. At Locality No. 3 I found evidence of two distinct layers in which they occurred at a vertical distance of two or three feet apart. But their general position is in the upper division, or *Hesperornis* beds, of the Niobrara, and the place to search is about the top of the blue chalk, and up into the yellow.

Grinnell and Williston have shown that *U. socialis* was evidently gregarious, living in swarms, whose individuals were inextricably entangled with one another by their arms and pinnules. This opinion is confirmed by my observations. In all the localities where the Crinoids occurred I did not find a single detached specimen. Every one of them was more or less entangled with others. So far as I know, the species has never been found in America, except where a colony of considerable number was indicated by the formation of a calcareous plate out of their skeletons. Most of those so far discovered were comparatively small; but the colony embedded at Locality No. 1 must have contained an immense number of individuals, since by far the greater part of the specimens were crushed into unrecognizable fragments, and cemented into a very firm limestone in the thicker portions. Erosion of the Niobrara Chalk beds has been most favorable for the fossil collector. They are cut up by several streams and hundreds of ravines, with innumerable little branches, producing miles and miles of splendid exposures. I know of no formation where the possibilities of a reasonably complete collection of its fossil remains are better than in this.

I mention this to emphasize the fact that the most careful search of these exposures, over an area of ten by twenty miles, by Mr. Martin and myself, and a greater area by Mr. Martin alone, has failed to disclose any trace of the Crinoids except where they occur in the colonies as above described. We looked especially for the detached plates, not only at the same horizon for miles, but also in the strata above and below it. Other fossils are abundant. The *Ostrea congesta* is everywhere, in immense num-

bers. The gigantic *Haplascapha,* whose shells are sometimes over four feet across, is almost equally prevalent. The sea must have swarmed with Mososauroid reptiles, of which upwards of two thousand specimens have been obtained in the region under consideration. But isolated specimens of *Uintacrinus* have not yet been found there; and in view of the exceptional opportunities presented for discovering the fossils which exist, it is fair to conclude that, as a rule, it did not occur in that way.

The colony of Locality No. 2 were all small ones; not a single specimen of a size at all comparable with most of those of the other localities was found there. Among the great numbers found at Locality No. 1, only a very few young individuals were observed, — probably not over a dozen in all, — and these were larger than the average of those at No. 2.

While on morphological grounds I see no reason to doubt that all the *Uintacrinus* thus far found in the Niobrara Chalk belong to one species, there is a special reason, based upon their evident gregarious habit and mode of occurrence, for believing that all the individuals of each colony belonged to the same species.

This would be in conformity with the known facts regarding the living Crinoids, both stalked and unstalked.

The stalked Crinoids of the present seas seem not only of wide geographical distribution for certain species, but also to be very gregarious in their mode of life. Mr. A. Agassiz, in his account of the dredgings of the "Blake" in the West Indies,* says of *Pentacrinus:* "We found them at Montserrat, St. Vincent, Grenada, Guadaloupe, and Barbadoes, in several places, in such numbers that on one occasion we brought up no less than one hundred and twenty-four at a single haul of the bar and tangles. We must, of course, have swept over actual forests of Pentacrini crowded together much as we find the fossil Pentacrini on slabs." *Rhizocrinus* is equally plentiful in West Indian waters, where Agassiz says † that on one occasion off the Florida Reefs "we must have passed over a field of Rhizocrinus with the dredge, judging from the number of stems and heads of all sizes which it contained."

The tendency to live together in swarms is equally characteristic of the unstalked Crinoids. The free floating Comatulæ also occur at times in colonies, and must float or swim about in vast numbers. Agassiz (*Op.*

* Bull. Mus. Comp. Zoöl., 1879, Vol. V., p. 296.

† Three Cruises of the "Blake," Vol. II., Bull. Mus. Comp. Zoöl., 1888, Vol. XV., p. 118.

cit. p. 118) says that *Antedon Sarsi* was brought up in thousands by the "Blake." Professor Verrill, in his account of the dredgings of the "Fish Hawk" for the U. S. Fish Commission,* says that *Antedon Sarsi* was found off the coast of New England in such profusion that over ten thousand specimens came up at a single haul of the dredge. A mass of Crinoids like this, suddenly killed, and settling upon a quiet, chalky, or muddy bottom, and becoming embedded there, would produce just such a limestone plate, with specimens preserved intact on the lower side, as those of *Uintacrinus*.

A similar mode of occurrence prevails with other Mesozoic Crinoids. In the Lias immense colonies of *Pentacrinus fossilis* (*P. briareus*) are found, whose remains form limestone bands of considerable extent. The Austins, in their Monograph of Recent and Fossil Crinoids, figure — at the end of the text, without number — a beautiful slab of this species, which shows very clearly how they occur. Professor Jaekel † states that the unstalked *Saccocomæ*, from the upper Jurassic lithographic slate at Solenhofen, lie so thickly together that twenty or more specimens may be counted on a slab the size of a hand, and that they must have lived in that sea in such prodigious numbers that he reckons them by millions.

So far as observed among the recent Crinoids, each one of the colonies consists of but a single species. Carpenter, in the "Challenger" Report on the Stalked Crinoids, pp. 139, 141, says, that the two species of *Rhizocrinus* were never found at the same station, either by the "Blake," the "Challenger" or the "Porcupine."

I have used the word "colony" in referring to the aggregations of these Crinoids as we find them. It seems to me this must be understood a little differently from the sense in which it is generally used in this connection. It could scarcely have been the ordinary condition in which the *Uintacrinus* was living, like the *Pentacrini* growing upon the sea-bottom, or the Comatulæ as they herd together among the rocks and coral reefs of our present shores. These Crinoids were in detached masses, clinging together and floating in the open sea, entirely separate from other objects. They were actually swarming, very much like a swarm of bees when they leave the hive and settle upon some object, — some on the outside and some buried underneath their fellows, — all in the utmost confusion. It must

* Am. Jour. Sci., February, 1882, p. 135.

† Ueber *Plicatocriniden*, *Hyocrinus* und *Saccocoma*, Zeitsch. d. Deutsch. Geol. Gesell., 1892, p. 684.

have been some peculiar condition which brought them together in this way, and it may have been the cause of their death. Dr. W. B. Carpenter * relates that on several occasions, when he placed a lot of Antedons in a basin of water and left them over night without any objects for attachment, they were all found dead in the morning, "conglomerated at the bottom of the basin, clinging to each other with their dorsal cirri, and having their arms intertwined in such a manner as to suggest the idea that they had died of asphyxia, produced by overcrowding;" while if a like lot of specimens were placed in a basin of the same size, with the same quantity of water, and a number of rough stones for a basis of attachment, all would be found in a healthy condition in the morning. The manner of preservation of these fossils is precisely what would result from such a conglomerated mass settling to the bottom and flattening out in the mud, producing a lenticular plate, thickest in the middle, and thinning out to a feather edge in all directions. What was the cause of their clinging together in this way, and why it is that in the Niobrara Chalk we find them only in this condition, are questions which I cannot undertake to answer. They had no cirri, and must have ordinarily led a free life, — probably pelagic, — for which, with their long and powerful arms as swimming organs, they were well equipped. They probably swam in schools, as Mr. Agassiz informs me the Comatulæ sometimes do when moving from point to point in Gorgonia groves. It is fair to presume that each of the deposits as we find them is the remains of such a school, which from some unknown cause became entangled in a confused mass, and perished in that condition. It is possible that this may have happened during periods of sexual activity. The living Comatulæ are unisexual, — the pinnules of some individuals bearing ova, and others spermatozoa.†

Another noteworthy fact is the entire absence in the Niobrara Chalk of other crinoidal life. In the English Chalk, according to Mr. Bather,‡ *Uintacrinus* occurs in the *Marsupites* zone, and in direct association with *Bourgueticrinus.* Schlueter § says that *U. westfalicus* is associated with the following forms: *Bourgueticrinus ellipticus, Pentacrinus cf. cingulatus, Marsupites ornatus,* and *Antedon Lettensis.* But here is not a sign of *Bourgueticrinus* (although it has been found in Alabama), nor of any other Echinoderm.

* Struct., etc., of *Antedon rosaceus*, p. 701.

† W. B. Carpenter: Struct., etc. of *Antedon rosaceus*, p. 690.

‡ Geol. Mag. N. S., Decade IV., Vol. III., p. 444–5.

§ Zeitsch. d. Deutsch. Geol. Gesell., 1878, p. 63.

The drawings for the illustration of the following pages were made by Mr. K. M. Chapman, teacher of art in the New Mexico Normal University at Las Vegas, and Mrs. E. Ricker, of Burlington, Iowa. It is a pleasure to acknowledge the zeal and intelligent interest with which they have labored to meet my wishes. The photographs were mostly made by Mr. Maurice Ricker, Principal of the Burlington High School, whose high scientific attainments and accurate methods, added to great skill with the camera, enabled him to afford me much valuable assistance.

STRUCTURE OF CALYX AND ARMS.

THE preservation of many of the Crinoids at Locality No. 1 is most excellent. The fine adherent matrix in which they were embedded can usually be removed by careful preparation, leaving the surfaces of cup-plates, arms, and pinnules exceedingly perfect; but it is useless to attempt to free the specimens from the parts of other individuals with which they are entangled on the slab. It is evident that the sea-bottom in which these fossils were deposited was extremely quiet and undisturbed by currents, so that the organic remains have been substantially unchanged as to their calcareous skeletons, except by chemical action, resulting partly from the decomposition of the soft parts. In many respects this new material confirms the account given by Mr. Bather. In the number and arrangement of the interbrachial plates, which is said to be the chief point of difference between the American species and *U. westfalicus*, there is the greatest variation, — much greater than Bather supposed. He states that they vary from 7 or 8 to 12; whereas the range of variation is actually from 3 or 4 to 23, as I shall show in detail later on. Clark's supposed definite plan of arrangement of these plates does not hold good at all. He says: * "The arrangement of the plates does not vary; seven in an oval band enclose the 8th, or 8th and 9th, according to the number of interradials." While this is a frequent arrangement, it is not at all a uniform one, as there are many cases where the number of plates is greater or less than that stated, and many in which they do not form a band enclosing one or more plates. The latter is true for those which have 3, 4, 5, 6, or 7 plates; these are disposed in two somewhat irregular vertical rows, with sometimes one of the plates forming a sort of apex at the top between the two proximal pinnules (Pl. V., Fig. 6); it is also true for many areas containing 8, and sometimes 9 or 10 plates. The variation in the interbrachial spaces is not confined to those of different individuals, but is almost as great in those of the same individual. One

* Bull. U. S. Geol. Surv., No. 97, p. 23.

specimen has 7 to 14 (Pl. V., Fig. 6); another 9 to 22 (Pl. VI., Fig. 5); others many different arrangements, as will be seen in the table hereafter given. The intersecundibrachs differ in a similar manner. Sometimes the interbrachial spaces are convex, and appear swollen, but generally they are about level with the brachials and sometimes depressed. Even the proximal interbrachial, which Bather calls "the only stable plate," is not free from variation. Sometimes it is replaced by 2, or even 3 plates (Pl. VI., Fig. 2). In some cases it lies between the radials, and extends down to the basals (Pl. VI., Fig. 6). There is no regularity about any of these variations such as might suggest the presence of an anal side; and from what we shall see farther on, we know that there is none. But when a large number of specimens are compared it distinctly shows that the number of interbrachial plates increases with growth of the individual.

The calyx plates are very thin, usually rather flat, though sometimes decidedly convex. They were evidently united by a very loose suture, as there is but little space on their edges for attachment of ligaments or for union by close suture. The faces are sometimes marked by faint, irregular, vertical grooves. The test must have been extremely pliant, as well as buoyant, since in proportion to the thickness of the plates it was of very large size.

Arms and Pinnules.

Grinnell estimated the length of the arms at one foot, or more. Hill, having traced an arm fragment for a distance of 17 inches, thought the arms must have been over two feet in length. Bather, from a calculation of the taper of portions of arms of the British Museum specimens, came to the conclusion that in an adult the length of a free arm branch was not less than 3 feet $3\frac{1}{2}$ inches, or 100 cm. My specimens prove that Bather's estimate was well founded, as we have the arm in one case actually preserved for a distance equal to his calculated length, with a probable addition of nearly a foot more. Specimen *a* on Slab VIII is in this respect the most remarkable that has been found (Pl. I., Fig. *a*). It was an adult individual, of nearly maximum size, — the calyx being 2.50 inches, or 62 mm., wide, and comparatively quite plump. Five of its arms are preserved to great lengths, — the longest one being 100 cm., or 40 inches, long, without reaching the distal end. The following measurements of brachials were made at different points on this arm branch: —

At 10th IIBr. . . .	length 1.50 mm. . . .	width 8.00 mm.
" 15 cm.	" 1.25 " . . .	" 4.00 "
" 30 "	" 1.25 " . . .	" 3.25 "
" 60 "	" 1.25 " . . .	" 2.25 "
" 90 "	" 1.00 " . . .	" 1.75 "
" 100 "	" 1.00 " . . .	" 1.50 "

The most rapid decrease in size of the arm is in the first 15 cm. The average rate of taper for the last 85 cm. is .25 mm. in width for every 8.5 cm. in length of arm, — or 1 to 340 mm. I have not been able to trace any of these long arms from the calyx to their distal extremity. I have, however, several terminal parts of arms preserved nearly to the end, and I find that as a rule they taper down to a width of about .50 mm. If we suppose the average taper of the above mentioned arm beyond the first 15 cm. to continue to the end, it would give a total length of 135 cm. It would seem, however, that the taper is a little more rapid towards the end, as the following measurements of three other specimens will show. The first is an arm branch of 83 cm. long, not traceable to its calyx; the second and third are parts of arm branches near the distal end: —

1.	At lower end . . .	length 1.15 mm. . . .	width 2.00 mm.
	" 15 cm.	" 1.15 " . . .	" 2.00 "
	" 30 "	" 1.15 " . . .	" 2.00 "
	" 60 "	" .75 " . . .	" 1.50 "
	" 75 "	" .75 " . . .	" 1.00 "
	" 83 "	" .75 " . . .	" .75 "

2.	At lower end . . .	length 1.00 mm. . . .	width 1.50 mm.
	" 11 cm.	" .75 " . . .	" 1.00 "
	" 18 "	" .75 " . . .	" .75 "
	" 24 "	" .50 " . . .	" .50 "

3.	At lower end . . .	length .80 mm. . . .	width 1.25 mm.
	" 10 cm.	" .75 " . . .	" 1.00 "
	" 15 "	" .62 " . . .	" .75 "
	" 20 "	" .50 " . . .	" .40 "

Taking the average of the taper for the upper part of the arm at about 1 to 250, it would add about 25 cm. to the length of arm of specimen *a* on Slab VIII, making it 125 cm., thus giving a total spread of arms of 250 cm., or 8 feet 4 inches, — a size far exceeding that of any other known Crinoid, recent or fossil.

A young individual on the same slab, having arms preserved to about 30 cm., gives the following measurements:—

At 10th IIBr	. . .	length	1.00 mm.	. . .	width	2.25 mm.
" 18 cm.	. . .	"	1.00 "	. . .	"	1.75 "
" 30 "	. . .	"	1.00 "	. . .	"	1.50 "

Allowing the same taper observed above for the terminal part of the arm, the arms of this specimen would be about 55 cm. long.

It will be observed that in the above measurements the distal brachials are about as long as wide, while the proximal, or those nearest the calyx, are five times as wide as long in the adult specimen, but only about twice as wide as long in the young. The absolute length of the brachials does not materially change, but remains nearly the same throughout the arm until near the distal end, where they shorten rather rapidly; but the ratio of width to length changes very greatly, especially in the adult individual. Near the calyx the brachials of VIII *a* are five times as wide as long, whereas near the distal end of the several specimens examined the length and width of the brachials are about equal.

The two specimens, VIII *a* and *b*, representing the adult and young forms, are shown on Plate I., just as they lie upon the slab, except that they are reduced to about one-fourth natural size. The plate was taken from a carefully executed drawing about half natural size, made by Mrs. Ricker, reduced by photography to its present dimensions. The slab contained numerous other specimens which were not drawn, except one or two which interfered with portions of the arms of VIII *a*.

There is a very extensive development of syzygies in these specimens. They occur throughout the arms in profusion, and there is a marked uniformity in their distribution in the proximal parts of the arms in adult specimens at intervals of 3 to 6; but farther up the intervals become much more irregular, and often longer. I give below tables of the occurrence of syzygies in several specimens from Locality No. 3, in which they are very plain, and also some from Locality No. 1, including one long arm of specimen I *xx*, to a length of 24 inches. In counting, I reckon the syzygial pair as two brachials; thus in the tables, the numbers given are those of the hypozygals. In some places, indicated by dashes or other signs, the positions of the syzygies could not be ascertained; otherwise the succession of numbers shows the actual intervals. The size of the specimens is indicated by the width of the calyx in millimeters.

TABLE A.

Distribution of Syzygies.

Specimen No. XX *a*. 22 mm.

Arm.										
I.	8	11	14							
II.	8	11	14	18	22	26	30	34	40	44
III.	8	11	14	17	21	25	29	33		
IV.	8	12	16		20	24	28	32	36	40
V.	8	11	14	17	21	25	29	33	37	

Specimen No. 78 *a*. 25 mm.

I.	6	10	14	
II.	6	10	15	20
III.	6	10	15	
IV.	6	10	16	

Specimen No. 3. 39 mm.

I.	9	14	20	24					
II.	9	16	19	24	28				
III.	9	15	18	23	28	33	38	44	49
IV.	9	16	19	24	28	33	38	45	49

Specimen No. 182. 51 mm.

I.	9	13	17	21	25	31	36	41	
II.	9	13	17	21	25	30	35	40	46
III.	9	13	17	21	25				
IV.	9	13	17	22	27	31	37		
V.	9	12	17	23					

Specimen No. 179. 53 mm.

I.	9	13	17	21	25	29	33	37	41	45	49	53	57			
II.	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65	
III.	9	13	17	21	25	29	33	36	40	44	48	52	56	60	65	69
IV.	9	13	16	22	27		32	37	41	45	49	53	57	62	66	70

Specimen No. 173. 56 mm.

I.	11	14		21	26	30	33	37	—	55	61	67
II.	9	13	17	21	26	31	35	40	44	55	62	
III.	9	13	17	21	24		35	40	45	54	61	67
IV.	9	13	17	21	25	28	—	—	—	54	60	66
V.		13	17	21	25	30		37	44	56		

Specimen No. 186. 62 mm.

I.	10	14	19	24	30	36	— none for 12 remaining brachials.											
II.	10	14	18	23	30													
III.	10	13	17	22	27													
IV.	11			23		(broken)		46	—	61	—	86	92	99	108	117	127	136	149

Specimen No. 178. 66 mm.

Arm.																
I.	9	13	17	21	25	29	33	38	44	49	54					
II.	9	12	15	18	21	25	30	36	42	48	54	59	66	72		
III.	10	14	16	22	27	34	39		45							
IV.	9	12	16	21	26	31		37	42	49	56	62	65	69	74	78
V.	10	12	15	19	24	29	34	40		47	54	61	66	71	75	

Single arm of Specimen I *xx*. 65 mm.

10 14 18 22 27 33 39 43 48 52 56 61 66 71 77 82 88 97 110
115 127 134 140 145 153 159 168 177 184 191 199 204 210 215 224 230 238 244
252 258 (about 50 vacant) 307 315 323 331 339 346 355 360 367 373 379 385 391
398 407 415 421 427 434 440 446 452 458 466

The distribution of syzygies can be studied on the photograph (Pl. VIII.) almost as well as upon the specimens themselves. The arms of several specimens are shown in the proximal portions, and the isolated parts of arms at A 3 and A 5 belong to specimen I *xx*, and end at a point about 24 inches from the calyx.

The syzygies are also well shown in specimens 117, 3, 78 *a*, and XX *a* (Pl. V., Figs. 1, 2, 3, 4). In No. 78 *a*, which is a young individual, it will be observed that the syzygies commence lower than in the others, — the first syzygial pair being the 6–7th.

The "skewing" of the brachials, resulting from the more or less diagonal position of the fulcral ridge upon the articulating faces of the plates, which has been well described and illustrated by Mr. Bather, is thoroughly shown by my specimens. The effect of this structure is to give extraordinary mobility and flexibility to the arms (Pl. VII., Fig. 8).

In the number of arms there is almost no variation. In one case, specimen X *e*, the first fixed pinnule has developed into an extra arm — thus making eleven arms in all (Pl. VI., Fig. 9); in another there are two extra arms similarly developed; in another — XIV *c* — there is an arm wanting (Pl. VI., Fig. 8); but these are the only departures from the normal number observed.

As to other variations from normal, I may mention that in one specimen, No. 1, the iIIBr plates are wanting in one ray, and in place of them is a large pinnule springing out of the axil (Pl. VI., Fig. 7); in another, I *g*, the iIIBr plates are wanting, and the space is unoccupied; in another, I *ii*, two of the iBr spaces are anchylosed into a solid, shield-like plate, the suture lines between the plates being faintly visible as raised lines.

The ventral side of the arms and pinnules has a broad, rather shallow

groove (Pl. VIII., Figs. B 7 and C 3), but shows no indication of any ambulacral skeleton. Neither covering plates nor side pieces are discoverable. I have specimens in which the preservation of these parts is exquisite; the ventral grooves are almost as sharp and distinct as in an alcoholic specimen. Considering the extremely firm and fine-grained chalky matrix, which has preserved even the membrane of the disk, and which I have with reference to this point cleared away under a strong magnifier with the finest instruments, I feel certain that if covering plates existed they would have been preserved, and would be visible in some of the specimens, no matter how delicate they were. From the fact that with such material as this the most careful search fails to disclose any trace of such plates, my experience in the preparation of many Palæozoic Crinoids leads me to feel entirely confident that there were none. In this respect *Uintacrinus* differs from the Pentacrinidæ and the Inadunata generally, so far as we know the structure of these parts.

As to the pinnules, their arrangement, structure, and shape, and the appearance of the ventral side of both pinnules and arms, no description could give half so good an idea as may be derived from a careful study of the photograph on Plate VIII. under a good magnifier. It is taken from a detail of slab No. 1, which is one of the finest examples of fossil preservation ever found. It was cleaned with great labor and patience by one of the most skilful preparators. The photograph is about .58 natural size. I am much indebted to Mr. Ricker and Mr. F. M. Fultz, of Burlington, Iowa, for their intelligent assistance in making this photograph. It is rare indeed to find in a single specimen such an amount and variety of information as is contained in this one. Almost every one of the important points discussed in this paper will find a good illustration on this plate.

In the proximal portion of the pinnules the pinnulars are much wider than long. They are wedge-shaped, widest on the dorsal side or back, and sloped toward the ventral side so that the inner edge is the thinnest — thus making the pinnule, in a side view, appear deeply serrated toward the ventral side. This facilitates mobility, enabling the pinnule to coil upon itself to some extent. But besides this there is a sloping outward of the lower side of each ossicle, so that seen from the back the pinnule appears deeply notched, or serrated on each lateral margin. This structure is well shown on Plate V., Fig. 1; and especially the photographic figure 5 on Plate VII. This sloping imparts a lateral bending or twisting motion to

the pinnule, and the effect of the structure is well shown by the bent and twisted positions they assume, like those of *Actinometra*, in contrast to the almost straight and relatively stiff pinnules of the Pentacrinidæ and many Antedons. The same structure prevails in the free part of the fixed pinnules, and by this character it can sometimes be seen at what point they probably became free.

The arrangement of the pinnules is generally as described by Mr. Bather. Several of the proximal pinnules are incorporated into the calyx walls by the upward growth of the supplementary plates of the interbrachial system. From four or five to ten of the lower plates of these pinnules are thus fixed. In adult individuals there are usually six, rarely eight, of these fixed pinnules to each interbrachial area. In the young there are sometimes apparently but four, and in still younger specimens only two. The intersecundibrach areas contain four fixed pinnules in mature individuals, and two, or sometimes apparently none, in the young. It is difficult to tell just where fixation of these pinnules ends. It is probable that in very young individuals there were none fixed. This would be in accordance with the plan of fixation of arms in *Strotocrinus* and some other Camerata, and of the pinnules in *Reteocrinus* and *Glyptocrinus*, with both of which there is a marked similarity in this respect.

The first fixed pinnule is given off from $IIBr_2$ on the outer side of the ray; the next from $IIBr_4$ on the inner side; the next from $IIBr_5$ on the outer side; the next from $IIBr_7$ on the inner side. The normal succession of the five lower pinnules may be conveniently represented by the numeral 24,578. Above this each brachial bears a pinnule on alternate sides, except where there is a syzygy, in which case only the epizygal is pinnule-bearing. There are occasional variations from the above arrangement, — *e.g.*, No. 78 *a* (Pl. V., Fig. 3), and No. 150 (Pl. V., Fig. 8), — but it is the general rule. It would seem probable from this that secundibrachs 1–2, 3–4, and 6–7 were primitively syzygial pairs, — the non-pinnulate first, third, and sixth plates being hypozygals. The latter is shown to be the case in specimen No. 78 *a*.

The following measurements of the second fixed pinnule in a large specimen will give a good idea of its proportions: —

Proximal pinnular	. . .	length 3.00 mm.	. . .	width 4.5	mm.
10th "	. . .	" .75 "	. . . .	" 1.25	"
25th free "	near top	" .50 "	. . . .	" .25	"

In a lower free pinnule of an adult specimen the measurements were: —

Proximal pinnular . . .	length .65 mm. . . .	width 1.75 mm.
Near distal extremity . .	" .50 "	" .25 "
Length of pinnule . . .	" 20.00 "	

The form and proportions of these lower free pinnules are well shown on the enlarged photograph, Pl. VII., Fig. 5.

Further up the arm the pinnules become more slender, and have less taper. A pinnular from the upper part of an arm measures .50 mm. wide and .40 mm. long; this pinnule is 14 mm. long, the length of the pinnulars remaining about the same throughout. Some of the upper pinnules are longer than this. The pinnulars in these are distinctly dice-box-shaped; this is more apparent towards the distal end, where they become proportionally more slender (Pl. V., Fig. 9). The tenuity of the pinnules in the distal part of the arms is extraordinary. They look like mere threads, and narrow to a point like a needle. Indeed, so extremely thin and delicate are they that it is only when they are cemented by pressure to some other object — such as calyx or arm plates — that they are preserved, or can be seen to the extremities (Pl. VIII., Figs. A 3 and A 5). The pinnulars in these parts are too slender to be measured by ordinary instruments, but they are at least three times as long as wide. The form and proportions of these very slender pinnules are shown best of all upon the enlarged photograph at Pl. VII., Fig. 6, where the pinnules are stretched out upon the black ventral side of a vertically crushed calyx.

COMPOSITION OF THE BASE.

One new fact is disclosed by these specimens, which will necessitate a revision of the description of the genus heretofore given, and that is in regard to the structure of the apical system, or base, of the dorsal cup. This is described by Mr. Bather* as consisting of, "(i) the centrale, or central apical plate; (ii) 5 interradially situate basals surrounding it; (iii) 5 radials surrounding the basals." As to the centrale he says: "Its

* Proc. Zoöl. Soc. London, 1895, p. 979.

homologies are therefore doubtful, as its structure and position permit it to represent either a relic of a stem, or a fused infrabasal circlet, or even, as some would have it, an additional element to which the term 'dorsocentral' might be strictly applicable." *

Further on, when comparing this genus with *Marsupites* and *Saccocoma* (p. 996), he says: "*Saccocoma* has a cup of nothing but radials; *Marsupites* has radials, basals, and infrabasals; *Uintacrinus* has no infrabasals, but in addition to its basals and radials, has brachials, interbrachials, interdistichials, pinnulars, and interpinnulars, all helping to compose its dorsal cup. . . . It is also noteworthy that each of these very differently constituted cups resembles the others in one curious feature, namely: the presence of a central, pentagonal, apical plate. One may say, if one choose, that in *Saccocoma* this represents the fused basals, and in *Uintacrinus*, the fused infrabasals; but in *Marsupites* it must be something else. Or one may say that in each case it is the same element, be it the proximal stem-ossicle (which some erroneously call 'centrodorsal'), or the distal stem-ossicle (which some, seeking an homology, have called 'dorsocentral'), or perhaps a new plate altogether, a simple supplementary plate developed to fill up the gap left by the disappearance of the stem."

Summing up, he says (p. 997): "The *essentials of structure* in *Uintacrinus* appear thus to be: 5 basals, 5 radials, 5 arms branching once," etc. This is a distinctly monocyclic base; and in seeking the derivation of *Uintacrinus* Mr. Bather elsewhere (p. 997) says: —

"Turning to the Inadunata, we have to choose between monocyclic and pseudo-monocyclic forms; since had the immediate progenitors of *Uintacrinus* well-developed infrabasals, one must suppose that these would have been retained and utilized to expand the walls of the cup, as in *Marsupites*."

In these observations Bather was perfectly justified by the material before him, and by the statements of previous writers. Hill † says: "In place of the sub-basal plates of the stemmed Crinoids, there is a small, five-sided centrodorsal plate, around which are grouped five pentagonal basals."

It now appears, however, that while the above description of the base is correct for many of the specimens, it is by no means uniformly the case. In a large proportion of them there is a distinct and well-developed circlet of infrabasals surrounding the centrale — thus producing a dicyclic base.

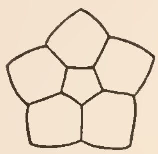
* Proc. Zoöl. Soc. London, 1895, p. 979.

† Kansas University Quarterly, 1894, Vol III., No. 1, p. 20.

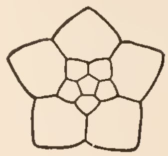
The discovery of this fact was announced by me in August, 1899.* The two forms of base are shown by the text figures below, viz.: —

Form M: Monocyclic; 5 basals and centrale. Fig. 1.

Form D: Dicyclic; 5 basals, 5 infrabasals, and centrale. Fig. 2.



1



2

The infrabasals of Form D consist of five small, usually pentagonal plates, which rest upon the sides of the centrale, in the line of the inter-basal sutures. Their superior angular points project upward a little distance between the basals, and the upper faces often have a slight petalloid convex curvature, to meet which the lower sides of the basals are correspondingly concave. This is the most common shape (Pl. II., Fig. 10). Sometimes the infrabasals are very acuminate, and their points project far up between the basals (Pl. II., Fig. 11). The infrabasals meet each other by interradial sutures, so that they form a complete ring separating the centrale from the basals. The exterior outline of this ring of plates is more or less stellate, and is often very similar to the outline of the ring of basals. The centrale in this form is a pentagon with straight sides, and its angles are directed interradially. The sutures between the centrale and the infrabasals, and of the latter among themselves, are perfectly distinct in numerous good specimens, and the plates are frequently found lying slightly apart, with the sutures more or less open, owing to distortion in the process of fossilization (Pl. II., Fig. 13, and Pl. VII., Fig. 3).

In Form M the centrale usually has the same shape as in the dicyclic form, but its angles are radial in position, instead of interradial, as in the latter.

Both of these forms are found in the large colony at Locality No. 1, and the relative frequency of their occurrence there is as follows: Out of 435 specimens showing the base —

244 belong to Form M = 56 per cent
191 " " " D = 44 " "

Crinoids of the two forms of base are often found in close connection,

* American Geologist, Vol. XXIV., p. 92.

with their arms interlaced. Pl. III., Fig. 1 shows the two in adult specimens, together with a young individual, in close contact. Other specimens from this locality of Form M are shown on Pl. V., Fig. 6, and Pl. VI., Fig. 6, and of Form D on Pl. III., Fig. 2; Pl. V., Fig. 7; Pl. VI., Figs. 1 and 2.

The photograph on Plate VIII. also shows the two forms in mature specimens occurring close together on the slab.

Both forms are also found in the colony from Locality No. 2, where out of 99 specimens showing the base —

24 belong to Form M = 25 per cent
75 " " " D = 75 " "

Specimens of Form M from this locality are illustrated on Pl. III., Figs. 3 and 5, and of Form D on Pl. III., Fig. 4.

The two forms also occurred together at Locality No. 6, where specimens showing the base are rare in the material as obtained. I have observed three belonging to Form M and one belonging to Form D, — all adult specimens.

The differences presented by Forms M and D are not correlated with any other characters. They have no apparent relation to size or maturity of the specimens, and therefore could not have been the result of differences in individual growth. The monocyclic form is found among the youngest specimens (Pl. III., Fig. 5) as well as the oldest; and the same thing is true of the dicyclic form (Pl. III., Fig. 4). Neither are they connected with variations in the interbrachial areas. I shall near the end of this paper give a tabulated statement of observations in these various particulars on more than five hundred specimens, by which the validity of the above assertions may be tested. Both forms are found in the same colonies, where all are inextricably tangled together; and I have no doubt that those in each colony floated together as one mass, and belonged to the same species.

Nevertheless, there are two distinct types of base among them. It is not a case where the infrabasals are concealed, or are more or less perfectly or imperfectly developed, or are fused with some other element, — as in some forms which Bather calls pseudomonocyclic. For here Wachsmuth and Springer's law of alternate arrangement of the elements of the Crinoid skeleton strictly prevails: —

a. When the infrabasals are wanting (Form M), the centrale is radial in position.

b. When the infrabasals are present (Form D), they are radial, and the centrale is interradial: —

Whereas in pseudomonocyclic and dicyclic forms the outer angles, or pentameres, of the stem — the next element below the base — are interradial, whether the infrabasals are visible or invisible.

In Form D the centrale does not seem in any wise to overlap the infrabasals, as if they were growing out from under it; but it lies distinctly within their circlet, and abuts by its five sides against the inner faces of the infrabasals. In these cases the centrale is often very small, — it and the ring of infrabasals together sometimes occupying but little more than the space of the larger pentagon when occurring alone. This is not always the case, as there are also frequent instances in which the centrale in the monocyclic form is no larger, actually or relatively, than the same plate in the dicyclic form, and occupies much less space than the infrabasals in specimens of equal size. In fact, the general rule is that the infrabasal ring is larger than the centrale is in monocyclic forms. The average of a number of specimens of 50 mm. width and upwards is, for Form M, centrale = 1.28 mm.; and for Form D, centrale = .97 mm., and IBB circlet = 2.35 mm. The infrabasals form a decagon, or five-pointed star, with more or less obtuse re-entering angles (Plate II., Figs. 10, 11, 12, 13), whereas the centrale in both forms is simply a pentagon with straight sides (Pl. II., Figs. 1, 2). The shape of the two is very distinct, and it is difficult to see how either one could have replaced the other under any circumstances, or at any stage of growth.

In Form M the centrale is subject to much variation in size, ranging from a maximum of 2.75 mm. (Pl. II., Fig. 1), to the minimum of .75 mm. (Pl. II., Fig. 2), and even less in one specimen. This variation has no definite relation to the size of the surrounding basals or radials, or of the calyx. In specimen No. 60 *a*, which is one of the largest in the collection, the centrale is no larger than in the smallest monocyclic specimens, and is indeed no larger than the minimum size of the centrale in adult specimens of Form D; and in No. 249 *c*, an average adult specimen, the exceptionally small centrale is not larger than that of small sizes of Form D. The following table shows the variations in the centrale and infrabasal ring in a number of specimens; the width of the calyx as it lies flattened, and also that of the basal and radial circlets, are also given for comparison. The measurements in this and all subsequent tables are in millimeters.

I have not seen an example of Form D in which there was no centrale.

TABLE B.

Showing variations in size of Centrale and Infrabasals.

Specimen.		Calyx.	Centrale.	Infrabasal circlet.	Basal circlet.	Radial circlet.
Loc. 2	LV *i*	7.50	.75		2.75	7.50
"	LV *m*	18.50	1.00		3.50	8.25
"	LV *b*	18.50	.75		2.75	7.50
Loc. 1	78 *a*	25.00	.75		4.50	11.25
"	20	44.00	.75		6.25	15.00
"	249 *c*	52.00	.40		5.75	14.00
"	25	51.00	1.25		6.25	15.00
"	XXIX *e*	56.00	.75		6.00	14.50
"	12	56.00	1.00		8.75	17.50
"	11	56.00	1.25		8.25	15.50
"	79	60.00	2.50		7.00	16.00
"	15	60.00	.75		6.25	14.00
"	I *x*	61.00	1.25		6.25	17.50
"	I *w*	62.50	.75		6.25	20.00
"	LXII *b*	62.50	.75		7.25	12.50
"	13	62.50	1.25		5.00	14.00
"	34	65.00	2.00		7.50	17.50
"	10	69.00	2.00		8.25	22.25
"	250 *a*	69.00	.75		7.75	15.75
"	23	69.00	1.50		8.75	20.00
"	I *ff*	70.00	1.50		10.00	21.00
"	60 *a*	70.00	.75		8.50	23.75
"	X *a*	72.00	2.75		10.75	24.00
	Average of	50. and up	**1.28**			
Loc. 2	K* 26	7.50	.25	.75	2.75	6.25
"	" 29	25.00	.50	1.25	3.50	8.50
"	" 3	27.00	.50	1.10	4.00	10.00
"	LVIII *a*	31.00	.50	1.00	5.00	10.00
Loc. 1	54	31.00	.50	1.25	4.00	9.25
Loc. 2	K 9	35.00	.75	1.50	4.00	10.00
Loc. 1	36 *b*	48.00	1.00	2.25	7.50	15.00
"	40	50.00	.65	1.75	7.00	14.50
"	XXIX *d*	50.00	.75	2.00	6.25	15.00
"	XI *c*	55.00	1.25	2.25	9.00	17.00
"	I *tt*	55.00	.75	2.00	6.75	15.00
"	88	56.00	1.00	2.50	8.75	16.00
"	42	60.00	1.25	1.75	6.75	16.75
"	45 *a*	60.00	1.00	2.50	8.75	18.75
"	I *hh*	61.00	.75	2.00	10.00	17.50
"	47 *b*	62.00	1.00	2.50	10.75	17.50
"	XI *a*	67.00	1.00	3.00	9.00	20.75
"	69 *a*	69.00	1.00	2.50	8.75	19.75
"	43	68.75	1.25	3.00	10.00	
"	LIV *a*	73.00	.75	2.50	9.00	18.00
"	IX *a*	74.00	1.25	3.00	9.00	19.00
	Average of	50. and up	**97.**	**2.35**		

* Specimens noted "K" belong to the Kansas University at Lawrence.

There are other variations which point still farther to an instability of the base. These are well shown by a series of figures on Plate II. Figs. 1 and 2 show maximum and minimum sizes of the centrale in Form M. In a few cases the centrale is somewhat elongate, and here its angles are more pointed than usual (Fig. 3). Then follows a series of specimens having respectively a centrale, and one, two, three, and four other plates (Figs. 4, 5, 6, 7). In studying the collection I found myself noting specimens like Fig. 4 as monocyclic, but having a "double centrale," and those like Figs. 5, 6, and 7 as dicyclic, with 2, 3, or 4 IBB. I had no special reason for this at first, but preserved the distinction on observing that in Fig. 4 both plates meet interbasal sutures by more than one angle. For the same reason it would probably be consistent to say that in Fig. 5 there is a double centrale and one infrabasal. It is important to note that in Fig. 6 the angles of the centrale next to the infrabasals are interradial, while those which abut directly upon the basals are radial. In Fig. 8 all five IBB are present, but unequally developed. In Fig. 9 the IBB are barely visible as minute points, which truncate the corners of the centrale, leaving it nearly round. In Fig. 10 the dicyclic base is fully developed. There are also to be found cases with only four basals, and with 6 basals (Plate II., Figs. 14 and 15).

All these irregular cases are rare and exceptional, and constitute mere individual variations.

Form D has the essential basal structure of *Marsupites*, viz.: basals, infrabasals, and a centrale. As to it, to this extent, the essential dissimilarity between the two genera pointed out by Mr. Bather (*Op. cit.* p. 996) does not exist, the calyx from the radials down being composed of the same elements.

The occurrence of this new Form D throws some light upon the homology of the centrale, — so far at least that it reduces the number of hypotheses that may be entertained regarding it. One of the suppositions heretofore suggested is disposed of: it cannot be (1) the fused infrabasals, because it is found here co-existent with them, a distinct element, situated within their circlet. There are thus left the other possibilities, viz.: (2) that it is the representative of the proximal or distal stem ossicle; or (3) "a simple supplementary plate developed to fill up the gap left by the disappearance of the stem." An objection to the second hypothesis is found in the fact that the centrale is located within the circlet of infra-

basals, and abuts against them by their *inner* faces, instead of by their outer or dorsal sides. It does not envelop or conceal the infrabasals, as the proximal columnal does in pseudomonocyclic forms; nor the basals and radials, as the representative of the stem in the Comatulæ usually does, — although there is an exception to that in the case of certain living species of *Actinometra*, and in many fossil Comatulæ. On the other hand, the orientation of the centrale is precisely as the stem should be; *i. e.*, interradial when the infrabasals are present, and radial when they are not. And the orientation is strongly against the third of the above suppositions. For the gap left by the disappearance of the stem, and to be filled up by stereom, would be the axial canal piercing the base of the calyx at the centre of the basal or infrabasal ring. This would be radial in the latter case, and interradial in the former. A supplemental plate developed to fill up this space should have the same orientation; but this is just the reverse of what is exhibited by the centrale. It seems to me, therefore, that the argument is decidedly in favor of the view that the centrale is a relic of the stem of the Stalked Crinoids, — if not, indeed, of the pedunculate stage of *Uintacrinus* itself.

There is no doubt that the occurrence of these two forms of base in this genus is a most extraordinary fact. Nothing like it has ever been observed before among the Crinoids, to my knowledge. Wachsmuth and Springer * held the presence or absence of infrabasals to be a good family character, except in case of the Reteocrinidæ, in which dicyclic and monocyclic genera — otherwise markedly similar — were included by us. It was the difficulty presented by these genera that prevented us from attributing to this character a higher value and wider significance. Mr. Bather,† on the other hand, considered the difference in the two forms of base as sufficient to separate the Crinoidea Inadunata into two sub-orders. He has lately, in the chapters on the Echinoderma in Part III. of Ray Lankester's Treatise on Zoölogy,‡ of which he was kind enough to send me advance proofs, elaborated a scheme of classification, embracing the whole of the

* Monograph Crinoidea Camerata, p. 174.

† Crinoidea of Gotland, 1893, p. 20.

‡ This portion of the work embraces a treatise on the Cystidea, Blastoidea, and Crinoidea. It contains a full morphologic and systematic account of the three classes, and their subdivisions down to genera. It brings into convenient form the results of all researches on both fossil and recent forms. Mr. Bather's conclusions will not all be accepted, but I wish to bear testimony to the great value of the work. Its comprehensiveness of treatment, lucidity of statement, and facility of illustration will render it of great use to students of these groups.

Pelmatozoa, on phylogenetic principles, in which he subdivides the Class Crinoidea into two sub-classes: Monocyclica and Dicyclica.

The validity of such a division of the Inadunata was combated and denied in the Monograph of the Crinoidea Camerata, upon grounds which it is not necessary to restate here. There was undoubtedly much plausibility in the suggestion of these two divisions, more as to the Inadunata than to the Camerata. What made it especially attractive was the fact that it was based upon differences in the primitive elements of the Crinoid organization, representing phylogenetically different early stages of the only Crinoid whose embryology we know. And the argument which was considered by its author to be conclusive, was the assumed fact that there was no such thing as a transition from one form of base to the other.

What, then, is the significance of the present discovery in relation to this question? It presents a difficulty far more formidable than the case of the Reteocrinidæ.

For those are Lower Silurian types,—among the earliest known Crinoids; and it is quite possible to suppose, if the Crinoids diverged into two lines of development on this character, that they represent stages somewhere near the point of such divergence. If the two forms of base represented by text figures 1 and 2 had been found in specimens otherwise separable, they would, under Mr. Bather's arrangement, have been unquestionably referred to different genera, families, orders, and sub-classes. Considering the apparent identity of these forms in every other point of structure, coupled with their mode of occurrence and association, I do not see how any such separation can possibly be made in this case. We therefore have apparently to deal with a case of individual variation, as to this supposed primitive character, within the limits of a species. That is to say, in this species, living in the same locality, having the same environment, floating in the same mass, certain individuals matured to represent one stage of larval development, *i. e.* with infrabasals, and others in another stage, *i. e.* with basals only.

In short, they are the two supposed distinct types, Monocyclica and Dicyclica, occurring in both young and adult of one and the same species. It will not do to say that the species is dicyclic, but in certain individuals the infrabasals are not developed, or are hidden by the centrale, or have disappeared by atrophy. If this were so, the centrale ought to be inter-

radial in both cases; whereas, as already shown, its orientation is reversed from one to the other, precisely as in typical monocyclic and dicyclic forms.

Such a condition I believe to be unique among the Crinoids. P. H. Carpenter * identified the infrabasals in the adult of four species of Ophiura, belonging to as many different genera, each of which embraces other species not possessing infrabasals. But never before, so far as I know, have the two forms of base been found in the same species. If Form D were an isolated occurrence, it might be treated as a case of sport, indicating a tendency to reversion to a dicyclic ancestor; but here the variation extends to nearly fifty per cent of the specimens, and we cannot say positively which is the normal form. At Locality No. 1, Form M predominates; but at Locality No. 2, Form D is largely in excess.

If it were a Pre-Silurian fossil, we might believe that we had found the point of incipient divergence of the two types; but here it occurs after the two have long passed their culmination. Nowhere before have we found any positive evidence of a transition, or direct evolution, of Dicyclica from Monocyclica, or *vice versa;* Bather and Wachsmuth and Springer are agreed on that point. But here we have a case of direct and immediate descent of one from the other, — though which way it was, we do not know. The direct progenitor of the monocyclic and dicyclic individuals of these colonies must have belonged to one type or the other. Hence it is that while the Reteocrinidæ might perhaps be disposed of by ignoring the family, and assigning their genera to other families of Monocyclica and Dicyclica respectively, such a course cannot be adopted here. Some other explanation must be sought of the fact that characters which seem to distinguish some of the largest divisions of the Crinoids are here found united within the limits of a single species.

It is difficult to frame an explanation of the co-existence of the two forms of base in these Crinoids. The plates composing them are extremely thin. There is no evidence of any kind of secondary growth or fusion in or about the centrale in the monocyclic form. There is no reason, based upon any characters exhibited by these specimens, for any inference as to one being prior in development rather than the other, unless it is the greater prevalence of Form D among the young individuals. If one was derived from the other during the life of the individual, it could only have been by one of three methods, viz.: (1) the resorption of the infrabasals in the dicyclic

* Quarterly Journ. Microscop. Sci., N. S. XXIV., Jan., 1884, pp. 1–23.

form; (2) their intercalation in the monocyclic form; or (3) the coalescence of infrabasals with the centrale.

To either of the first two, the orientation of the centrale presents a morphological difficulty so great that I do not see how they can be entertained. A resorption of the infrabasals in the dicyclic form would leave the centrale interradial in the resulting monocyclic base, which is contrary to the fact; the intercalation of infrabasals in the monocyclic form would leave a radial centrale in the resulting dicyclic base, which is equally contrary to the fact, — unless, during this process in either case, the centrale should at the same time undergo a revolution from interradial to radial, or *vice versa*, or should be reduced by the truncation of its angles until only an interradial pentagon should be left. That such a movement or reduction may have taken place in the larval stage — governed by causes we know nothing about — need not be doubted. But that they could have occurred among the hard parts of the Crinoids, after they had reached any stage of growth such as we find in the fossil condition, is contrary to everything hitherto known touching the mode of growth of these organisms. There are a few cases, as before stated, in which the infrabasals are very minute, not large enough to affect the position of the centrale by crowding it, — but there is no sign of any revolution or shifting; and the effect of the truncation of the angles in these cases is to make the centrale a decagon, — practically almost round.

A coalescence or fusion of the infrabasals with the centrale would not be subject to the same objection on the ground of orientation. The resulting plate would be radial, as it should be in a monocyclic form. But there are other difficulties in the way of this method equally insurmountable, in my opinion. Among the 268 dicyclic specimens examined by me I can scarcely point out one in which the coalescence of the infrabasals and centrale would produce a plate having the same outline as the centrale has, or which would not be entirely distinct in shape from the centrale in most of the 275 monocyclic specimens in the collection. The centrale is *never stellate*, while the infrabasal ring is almost always more or less so.

Hence in order to successfully transform the infrabasals plus the centrale into a centrale alone, the process must change not only the outline of the infrabasals, but that of the surrounding plates as well, — which would mean not only the fusion of infrabasals with centrale, but a modification of the shape of the basals also. The relative size of these plates is also against it.

In many cases the centrale of Form M is much smaller than the combined infrabasals and centrale of Form D, in specimens of corresponding size; and it is sometimes smaller than the centrale alone. For instance, how could the centrale of such specimens as Nos. 249 *c*, 12, 15, I *w*, 250 *a*, and 60 *a* (Table B) have been produced by the fusion of infrabasals and centrale in specimens like Nos. 40, 88, 42, 47, 69, and 43? As the table shows, the average for a number of adult specimens is, for Form M, centrale = 1.28 mm., while for Form D, the infrabasal circlet = 2.35 mm.

As I have already stated, there is no evidence in the specimens of any fusion among the plates. Whatever tendency can be detected in the fossil condition is rather the other way. In the more mature specimens of Form D, in which the plates have become much thicker and firmer than in the young, the sutures among the infrabasals, and between them and the centrale, not only become more distinct than is frequently the case among young specimens, but they often appear somewhat separated, or disturbed among themselves, through pressure in fossilization. Examples of this are given on Plate II., where Fig. 12 shows the infrabasals disturbed and partly raised out of position, and in Fig. 13 they are well separated. But the most complete case is that of Fig. 3 on Plate VII., where I have given an enlarged photograph of the base of No. 247, with the infrabasals lying entirely apart from each other and from the centrale. If there is any tendency among the plates of the dicyclic base, exhibited by the fossils, it is to become more distinct and well marked by growth.

Even this would not end the difficulties. Mr. Bather, by a beautiful series of observations and illustrations,* has demonstrated that the presence or absence of infrabasals is correlated with the radial or interradial position of the lobes of the chambered organ, which lodges the nerve centre coordinating the muscular movements of the whole skeleton. That is, if the base be monocyclic, the lobes of the chambered organ correspond with the basals, and are interradial; and if the base be dicyclic, the lobes of the chambered organ correspond with the infrabasals, and are radial. Hence, as he says, "the derivation of one type from the other involves more change than the mere atrophy or appearance of certain plates." Now, according to this, in Form D of *Uintacrinus*, whether old or young, the lobes of the chambered organ would be radial, and the branches of

* Geol. Mag., Decade IV., Vol. V., pp. 422–425, Sept., 1898; also Ray Lankester's Zoölogy, Chap. XI., p. 104.

the axial nerve cords passing down from the radials would meet at about the centres of the basals, and again fork toward the infrabasals; while in Form M, whether young or old, the lobes of the chambered organ would be interradial, and the branches of the axial nerve cords from adjacent radials would meet about the centres of the basals and not fork again, but pass directly into the chambered organ. A transformation of one form into the other, as a result of individual growth, would therefore involve, in addition to the change in orientation of the centrale, a revolution of the chambered organ, and an extension or shortening (as the case might be) of the downward prolongations of the axial nerve cords. It may be suggested that owing to the absence of a stem such changes might be accomplished with less difficulty than would exist in stalked Crinoids. But it seems probable, from analogy with the life history of *Antedon*, and what we know of *Actinometra meridionalis*, that these Crinoids had stems in the larval stage. And it is difficult to imagine how such changes could possibly have taken place, in either stalked or unstalked Crinoids, after the larval or pentacrinoid stage was passed, and the position of the hard parts of the skeleton became fixed.

Furthermore, none of the above methods would account for the facts as we find them. What shall be said of cases such as are presented by Figs. 1 and 2 of Pl. III.; 6 and 7 of Pl. V.; and 1, 2, and 6 of Pl. VI., where the two forms of base are found fully developed in specimens of the largest size, or by Figs. 3, 4, and 5 of Pl. III., where they are equally distinct in very young individuals? These are not isolated cases, as may be seen from the Table F *infra*, which shows that the two forms occur indiscriminately among old and young, with a considerable predominance, however, of the dicyclic base among the younger specimens, and a slight excess of the monocyclic base among the older ones. Among specimens measuring under 25 mm. across the calyx, 75 per cent are dicyclic; while among those of maximum size — 50 mm. and over — the proportion of dicyclic is about 40 per cent. If there were a tendency to develop by individual growth into either form, then we ought to find practically all the adult specimens belonging to that form; and the same thing would be true if the transition took place during the larval stage. The great number of well-developed individuals of each type — so great that, as before remarked, we do not know positively which was the normal form, or if there was one — is in my opinion a fact totally inconsistent with any of the above sup-

positions. The cases of imperfect development in size or number of infrabasals (Pl. II., Figs. 4 to 9) may correspond to stages of transition from one form to the other.

We have, therefore, in pursuing this matter farther, to choose between these alternatives: (1) That from the eggs of either a monocyclic or dicyclic Crinoid both forms were indiscriminately hatched; or (2) that they hatched in one form, with a tendency in the larva to develop into the other, which tendency irregularly became effective in some individuals, and ineffective in others; or (3) that after the larval stage, by some process of addition, subtraction, or consolidation among the hard parts of the test, a dicyclic Crinoid was transformed into a monocyclic, or *vice versa.* Whichever of these be accepted to account for the observed facts in *Uintacrinus*, we have no reason to say that the same thing may not have occurred in other Crinoids, from the earliest Palæozoic times. And if so, the transition from the one form of base to the other would seem to be not so difficult or impossible as has been assumed. Nor does it seem that this character can be taken with such absolute certainty as the leading one upon which — above all others — the phylogenetic classification of the Crinoids must be based, and to which all other characters must yield. If within a single species, dicyclic and monocyclic Crinoids can by some of these processes be indiscriminately produced, where is the difficulty in conceiving that both monocyclic and dicyclic genera might have arisen in some similar way, and flourished side by side within the limits of a primitive family like the Reteocrinidæ? If one can be derived from the other ontogenetically, why not phylogenetically, within orders, sub-orders, and families?

The relative importance of characters as evidence of descent is, and must remain — at least when dealing with extinct forms — largely a matter of individual opinion. It has often been said that every scheme of classification is only an expression of the opinion of the author at the time of its promulgation, and I do not see that this statement loses much of its force with the progress of investigation. Whether, in the arrangement of the Crinoids, Dicyclica and Monocyclica shall be held to be subdivisions of the great groups of Camerata, Inadunata, and Flexibilia, or of lesser divisions, or whether these shall be considered as subdivisions of the Monocyclica and Dicylica, cannot, in my judgment, be settled with our present knowledge. Which way the thread of consanguinity was

carried we cannot tell. We may speculate, and I have no fault to find with those who do so, for speculation not unfrequently opens up the road to discovery.

Mr. Bather * has criticised the Monograph of the Crinoidea Camerata, because its authors did not, in his opinion, construct a classification on phylogenetic principles; and in his larger review † we are treated to some good-natured banter for our "uninteresting prudence" in refraining from the cultivation of genealogical trees. We are told that an author should "have the courage of his convictions," and that the "downfall of so many phylogenetic erections is due to the fact that they are built with their foundations in the air." And in Lankester's Zoölogy, Part III., p. 141, he says that "Wachsmuth and Springer's system, though far the best from an anatomical standpoint, is not the classification sought by the modern biologist."

There is no doubt that each author who undertakes to express his ideas of descent in a new scheme of classification does so in the belief that his own structure is a substantial pyramid, whose base is firmly established upon the ruins of the top-heavy contrivances of his predecessors. With regard to the Crinoids, there have appeared, since our Monograph of the Camerata, two elaborate classifications, each avowedly based upon phylogenetic principles, viz.: that of Mr. Bather, already mentioned, and one by Dr. Jaekel, whose general researches and great works upon the Crinoids of Germany constitute a rich contribution to science. The views of the latter author are to be developed in full detail in his magnificent "Stammesgeschichte der Pelmatozoen," the first part of which, embracing the Thecoidea and Cystoidea, has just been published. He, likewise, ‡ finds fault with Wachsmuth and Springer, because, in his opinion, they have dealt with the morphological conditions as they found them too much from an anatomical standpoint, and have not sufficiently taken into account the import of the modifications due to descent. He finds in the changes in the systematic arrangement of the Crinoids made by Wachsmuth and Springer in their successive writings, proof that the right road to the solution of the great questions of classification had not yet been found.

We have, therefore, two new and almost simultaneous phylogenetic

* Natural Science, May, 1898, p. 345. † Geol. Mag., Decade IV., March, 1899, p. 123.

‡ Neues Jahrb. f. Min., 1899, Vol. I. p. 380. Sitzungsberichte Ges. Naturf. Freunde zu Berlin, 1894, p. 102.

classifications, by two of the most eminent living authorities, both predicated in part upon the insufficiencies of Wachsmuth and Springer's system, and each believed by its author to be a new and correct reading of the race history of the Crinoids. From such sources, and following such a preface, we should not unnaturally expect a brilliant illumination of the road, in search of which their predecessors have floundered in darkness. But to our dismay we find that instead of celebrating a conclusive settlement of these questions, we are only invited to witness fresh controversy. For these new chroniclers do not read their history alike, and their two classifications are about as diametrically and fundamentally opposite as anything could be.

Mr. Bather finds in the presence or absence of infrabasals ground for a primary division of the Crinoids into two sub-classes, independently developed from unknown ancestors, viz., Monocyclica and Dicyclica, of which the Camerata and Inadunata are only subordinate divisions found in each of the primary groups; and he splits the Camerata in two, because he thinks the Platycrinidæ and their allies are too inadunate in their characteristics to be allowed to remain there.

Dr. Jaekel, on the other hand, does not recognize the dicyclic or monocyclic base as affording ground for large divisions at all. He has a better opinion of the Camerata, however, for he erects them into a sub-class under the name of Cladocrinoidea, which he separates from all the other Crinoids because he believes its representatives descended independently from some of the many-plated Cystids; and the Platycrinoids he firmly retains within this group. The remainder of the Crinoids he groups in a sub-class of equal rank with the Camerata, under the name Pentacrinoidea, within which are to be found the Fistulata (W. & Sp.), Larvata (Larviformia W. & Sp.), Costata, Articulosa (Articulata W. & Sp.), and Articulata (*sensu* Joh. Müller). Monocyclic and dicyclic forms occur indiscriminately throughout each of his basic groups.

While, therefore, we may admire the boldness and skill of these two distinguished adventurers upon the stormy sea of speculation, and may await with "interest" the survival of one or the other of the antagonistic conclusions to which their phylogenetic excursions have led them, others of us, who have not felt quite ready to embark, may perhaps content ourselves yet awhile with paddling along close to the shore, however "uninteresting" our modest ventures may be.

It may be that "Monocyclica Camerata" represents a nearer approach to the fact of nature than "Camerata Monocyclica," or simply "Camerata"; but I am not yet convinced of it. Whether evolution of the Crinoids was in all cases along the line of basal, or of tegminal, development, we cannot tell. If we are to be guided alone by the embryology of *Antedon*, we should be inclined to say it was the former. But I am by no means sure, as has been suggested by both Neumayr and Carpenter, that we are justified in judging the phylogeny of the entire class by what we know of the ontogeny of a single genus, which cannot be said to be, in all respects, a typical one.

The two forms run together so closely in the Lower Silurian that Wachsmuth and Springer were unable to separate them more than generically. And in many Mesozoic and recent Crinoids the dicyclic character is so completely lost in the adult that they were classed as monocyclic by everybody until our discovery of the law of alternation made it possible to recognize the dicyclic plan where the infrabasals are either concealed by the stem, or totally obliterated by growth. Even then our statement that the Comatulæ are built on the dicyclic plan was unmercifully criticised and ridiculed by P. H. Carpenter, until Bury's discovery of the infrabasals in the larva of *Antedon* settled the question.

At all events, we have in *Uintacrinus* perfect proof that in some cases the characters of a monocyclic or dicyclic base are subordinate to others, and do not mark the line of descent.

STRUCTURE OF THE TEGMEN.

An entirely new fact, which must be taken into account in discussing the relations of *Uintacrinus*, must now be considered, and that is the morphology of the ventral disk or tegmen, which is now for the first time brought to light. Hill, in describing the fine material acquired by the Kansas University in 1894, expressed the opinion that "from the shape of the Crinoid, its globose form, and long, heavy arms, one would hardly expect to find any of the ventral plates exposed, and such is the case. Nor has it been possible to expose them by dissecting

away the plates." Bather, with the British Museum material, was equally unsuccessful.*

Hill's reasons for not expecting to find any of the ventral plates are not good. There is nothing in the globose form or heavy arms to prevent the preservation of the disk, any more than in any other form or style of arms. That which did render its discovery improbable was the pliant test, which was always crushed more or less flat. On this account the only chance was to find a case where the Crinoid had settled down into the soft ooze with its arms outstretched and ventral side down, so that it should be flattened vertically instead of transversely, and the disk at the same time be pressed into the plastic matrix. For these I kept a sharp lookout while taking out the specimens at Locality No. 1. In several specimens where the arms or calyx plates were broken off, I soon discovered the existence of a large, funnel-shaped anal tube, which was unknown before. Some specimens were found from time to time in the desired position for exposing the disk, but most of them proved a disappointment, as the disk was destroyed, and only the large calyx plates showed through. Finally, however, some such specimens appeared in that part of the layer where the preservation was the best, having the ventral side deeply covered with a firm and exceedingly fine-grained bluish chalk, or calcareous mud. On removing this with fine tools and brushing, I came to a jet black surface, which seemed to be the remains of a carbonaceous integument, studded with small, irregular calcareous granules, of lighter color. It was so frail, thin, and brittle, that parts of it scaled off with the least touch, and the first specimen exposed gave but little idea of the nature of the disk, and no hint at all of the remarkable facts afterwards disclosed. The other specimens were left for future cleaning, when by the exercise of the greatest care, and the most delicate manipulation, mostly under a magnifier, I was rewarded by the exposure of a perfect disk, which exhibited, to my astonishment, a *central anal protuberance, and marginal mouth*, — a type hitherto unknown among Crinoids, recent or fossil, with the exception of the Comatulid genus *Actinometra*, and perhaps the Triassic *Holocrinus*. Several others were afterwards developed, which brought out various details in such a manner, that the form and structure of this portion of the Crinoid could be studied almost as well as in specimens dredged from the ocean. The preservation is most beautiful;

* Proc. Zoöl. Soc. London, 1895, p. 979.

with a considerable experience among fossil Crinoids, I have never seen anything to surpass it.

The Disk.

The disk is composed of a plated skin, the membrane being of such a highly carbonaceous composition that it is jet black in the fossil. This membrane evidently enclosed the entire visceral mass, and formed a lining underneath the calyx plates, where it is usually seen when the plates are broken away (Pl. III., Fig. 1). Upon the disk it is studded or paved with small calcareous plates or spicules, which are not connected by suture, but are embedded in the integument without touching each other (Pl. VII., Fig. 2). They are of irregular shape, variable in size, and without any definite plan of arrangement. The variation in size exists in the same specimen, and between different specimens. In No. 71 (Pl. IV., Fig. 2), and also at C 3 on Plate VIII., the plates are mostly very small, but a few large ones are scattered throughout the disk. In No. 75 (Pl. IV., Fig. 1) they are quite large and prominent, their light color contrasting sharply with the coal black perisome in which they lie. The only suggestion of arrangement of these spicules is about the base of the anal tube, where they sometimes take a vaguely concentric position, indicating the curvature of the tube, and along the ambulacral grooves, where there is a semblance of linear and alternate arrangement. The spicules are of a porous structure, wholly different from the dense limestone which composes the calyx plates and brachials. All the details of the disk may be seen and studied under a glass upon the enlarged photographic figure made by Mr. Ricker, with infinite care and pains, from the wonderful specimen, No. 75 (Pl. VII., Fig. 1). The porous nature of the spicules can be clearly seen in it. A greater enlargement of a few spicules (Pl. VII., Fig. 2) shows their irregular shape and how completely independent they are of any connection with each other.

Anal Tube.

The central part of the disk is occupied by a large, conical anal tube, shaped like an inverted funnel, which is perhaps an extension of the integument above described. It is also composed of a plated skin, the granules of the disk passing gradually into it, and becoming more and more elongate, until toward the distal end, where the opening was, they become thread-like. Yet the tube can be distinguished at once from the disk by its color. It is

remarkable that the color of this tube should be so different from that of the disk, out of which it seems to rise; and yet while the disk is of a bright jet, shining like coal, the tube is of a purplish color, light at the base, growing darker towards the extremity, which is often quite dark, but totally distinct from the inky blackness of the disk. The spicules composing the tube lie in close contact, and are apparently not so porous. In specimen No. 71 (Pl. IV., Fig. 2), where the tube is curled upon itself and flattened upon the disk, these differences in color are distinctly observable. The tube is variable in size, probably owing to the greater or less distension of the gut at the death of the animal. It is found in the fossil state in almost every conceivable position. An excellent representation of these variations is given on Plate IV.

In specimen No. 75 (Pl. IV., Fig. 1; and Pl. VII, Fig. 1), the tegmen is in its natural position, the Crinoid having settled disk downward into the soft mud, and thus been compressed vertically; the tube lies flat, stretched out upon the disk to its full length, the tip extending a little beyond the margin of the disk. The shape of the calcareous plates or granules, both in the disk and tube, and the contrasts in depth of color, are beautifully shown in this specimen. The tube is 18 mm. in height.

In No. 71 (Pl. IV., Fig 2), which is also vertically compressed, the tube is twisted and crushed upon itself, and entirely flattened, with its dark tip lying in the middle, where it looks more like a depression than a projection.

In No. 76 (Pl. IV., Fig. 3), a moderately large individual, with calyx about 47 mm. wide, and compressed between a lateral and vertical position, the tube rises above the level of the free arm branches to a height of 15 mm. In a number of other specimens which were laterally compressed, the tube is seen in its natural position rising between the arm bases.

In No. 148 (Pl. IV., Fig. 4) the black disk has been itself forced upward by the lateral compression of the calyx, and appears as a conical elevation, which has been exposed by breaking away some of the arms. Surmounting this the purple, funnel-shaped tube, which is very large in this specimen, rises to a height of about 19 mm., its distal end being about the height of the 28th secundibrach.* It is 12 mm. wide at the bottom. Allowing for

* It will be noted that I do not use the same terms for these and other plates in the brachial series which were employed by Wachsmuth and Springer in the Monograph of the Crinoidea Camerata. I adopt instead, and shall hereafter use, the nomenclature and symbols for these parts proposed by Mr. Bather in Lankester's Zoölogy, Chap. XI., p. 143, and previous papers, as being the most philosophical and accurate, and being also the logical consequence of our own researches. When in 1881 (Revision, Pt. II., p. 10)

the flattening, it must have been at least 7 mm. in diameter where it emerged from the disk. The dark tip, slightly twisted, is very distinct.

In No. 150 (Pl. V., Fig. 8) the removal of three arms has exposed the anal tube, but none of the disk. The tube is 12 mm. high, and 12 mm. wide at the base; it rises to about the height of the 25th IIBr.

In No. 30 (Pl. IV., Fig. 5) the tube is shown in a singular position, but one which is readily understood if we bear in mind the method of fossilization as I have described it above. Here the compression was between lateral and vertical, and the disk, instead of being forced upward between the arms, as in No. 148, was pushed downward, and thus caught between the walls of the calyx in the concavo-convex position they took in settling into the mud. Some plates of the lower (now outer) side of the calyx being removed, the tube and part of the disk are now seen flattened against the opposite wall. Several cases of this kind have been observed. In this specimen the black carbonaceous lining beneath the calyx plates is exposed.

Mouth and Ambulacra.

The mouth is excentric, and the ambulacra diverge from a point near the margin of the disk. Two of them follow around the margin in a large horseshoe curve, enclosing the anal tube. These branch on either side so as to connect with the arms of the posterior rays. The next pair of ambulacra are shorter; they branch and supply the two lateral rays. A single groove runs to one branch of the anterior ray, and the other branch does not seem to have any groove leading to it. This is the arrangement of ambulacra in specimen No. 75 (Pl. IV., Fig. 1), which shows them the plainest. It is very similar in No. 71 (Pl. IV., Fig. 2).

and 1885 (ibid. Pt. III., p. 12) we showed that the arms fundamentally begin with the second plate of the ray, *i. e.* that all plates of the ray above the "first" radials, whether free or not, are "brachials," it logically followed that they ought to be designated according to their numerical succession. We, in fact, proposed to use the terms "primary," "secondary," and "tertiary" brachials, etc. Upon conference with P. H. Carpenter, who thought these terms too long and cumbrous, we agreed to use "costals," "distichals," and "palmars," as proposed by him. (Ann. and Mag. Nat. Hist., Ser. 6, Vol. VI., pp. 11–18; Proc. Acad. Nat. Sci. Phil., Oct., 1890, pp. 374–5.)

In the Monograph we retained, in an explanatory sense, the alternative terms, "primary brachials," "secondary brachials," "tertiary brachials," followed by "brachials of the fourth order," and so on, and employed for these the symbols I., II., III., IV., &c. (Mon. Crin. Cam., pp. 73–75). Bather's invention of the terms "primibrachs," "secundibrachs," etc., and the other terms naturally accompanying them, with their convenient symbols, was a solution of the difficulties, and gave us a terminology for these parts of the Crinoid skeleton at once so consistent, convenient in use, and easy of remembrance, that I am sure it must win acceptance by all who will take the trouble to understand it.

In No. 76 (Pl. IV., Fig. 3) there are traces of the ambulacra only at the lower left corner, where three are visible, evidently at the anterior side, close to the mouth. They cannot be followed, owing to the way the specimen is crushed.

It is to be observed that in all these specimens, as well as in some others in which the ambulacra are less plainly visible, the tube always lies pointing away from the mouth.

Parts of the ambulacra are to be seen on several other specimens, and enough is shown to prove, beyond the slightest doubt, that the position of mouth, ambulacra, and anal tube, as above described, is constant.

The ambulacral grooves are simply depressions in the perisome. The granules with which they are studded are sometimes smaller than in the rest of the disk, and along the lateral margins of the grooves they are somewhat marked by linear rows, while in the middle they sometimes have a semblance of alternate arrangement. But both at the sides and in the middle the spicules are of the same irregular shape and spongy texture as in the other parts of the disk. The grooves themselves are broad and shallow, which is probably due to the flattening of the disk by pressure. There is no trace of any covering plates, or anything like an ambulacral skeleton; and from the manner in which the grooves are preserved, it is perfectly evident that there never were any. There is no doubt that every solid structure pertaining to the disk was preserved, just as it was embedded in the soft mud, which formed a firm but exceedingly delicate mould. The plates of the tube are very fragile, yet they are perfectly preserved. The matrix was an impalpably fine, impure chalk, well adapted to preserve every part in place; so that it may be regarded as certain that no portion of the calcareous skeleton has been lost.

It will be well now to consider what other tegmens have been found in fossil Crinoids, with which, as well as with those of living forms, that of *Uintacrinus* might be compared.

The tegmen of the Camerata is so widely different, being a solid structure composed of definite plates, with mouth and food grooves rigidly covered, that there is no need of comparing it.

Among the Flexibilia * (= Articulata, *sensu* W. & Sp.) there are a number of interesting cases. In the Palæozoic genus *Taxocrinus* the ventral surface is covered by an integument of very small, irregular, calcareous pieces, on the surface of which five well-defined ambulacral grooves, with covering plates and side-pieces, converge in the centre and pass down into an open mouth between five large and conspicuous oral plates.†

The mouth is central, and the anal tube originates laterally, well down between the two posterior rays. It is probable that the tegmen of the Flexibilia generally was of a similar nature.

In the Jurassic genus *Apiocrinus*, according to Loriol, ‡ who found it in a specimen of *A. roissyanus*, the ventral disk has the form of a conical sac, covered with irregular, thin plates, rising from the heavy interbrachials. No ambulacral grooves could be traced, nor could the position of the mouth be determined. Mr. A. Agassiz § is inclined to consider the conical sac of de Loriol's specimen the anal proboscis, — a surmise which I think highly probable, in view of the similar form and appearance of the anal protuberance in *Uintacrinus*. But whether it was central or not we cannot learn from the specimen.

Calamocrinus,‖ the recent representative of the Apiocrinidæ, has a tegmen composed of small plates suturally connected ; the mouth is central, ambulacral grooves roofed by movable covering plates, and the anus is at the end of an excentric tube.

In *Rhizocrinus*, the living representative of the Bourgueticrinidæ, the mouth is central, protected by five small oral plates, which occupy the central ends of the interpalmar (interambulacral) areas ; the remainder of these areas is not plated ; the ambulacra have covering plates, but no side plates.

* So much confusion has arisen from the use of J. S. Miller's name "Articulata" in different senses, that I do not consider it advisable to retain it in the sense used by Wachsmuth and Springer in our Revision and Monograph. In the latter work (p. 153) we intimated our misgivings in regard to it, and suggested an alternative name "Articulosa," which proved to be preoccupied by Jaekel for a group a little differently limited. Von Zittel has proposed "Flexibilia" for the same general group as ours. It is appropriate, free from confusion, and in all respects preferable. I propose to adopt it in a future work embracing this group, and will therefore use "Flexibilia" in this paper, with the understanding that it is the equivalent of Articulata as defined by us in the works above mentioned.

† Wachsmuth and Springer. Discovery of the Ventral Structure of *Taxocrinus*. Proc. Acad. Nat. Sci. Phil., 1888, p. 345, Pl. XVIII., Fig. 1 *e*.

‡ Note sur quelques Echinodermes fossiles des environs de la Rochelle. Acad. de la Rochelle, Société des Sciences Naturelles de la Charente Inférieure. Annales de 1886, Tom. XXIII., 1887, p. 313.

§ *Calamocrinus Diomedæ*, p. 42. Mem. Mus. Comp. Zoöl. at Harvard College, Vol. XVII., No. 2, 1892, p. 42.

‖ Ibid.

Among the Palæozoic Inadunata, so far as known, the mouth is subtegminal, and the ambulacra either subtegminal or covered with strong, apparently rigid plates. In the Fistulate division a great development of the posterior interradius into an elongate ventral sac in many cases tended to push the oral centre to one side, so that in genera like *Scaphiocrinus*, *Scytalocrinus*, *Decadocrinus*, etc., the mouth must have been subcentral or marginal. Whether it remained so in the Mesozoic Encrinidæ, in which the ventral sac had almost disappeared, cannot be determined from the material thus far discovered, — although it seems probable, if the structures described by Wagner and von Koenen are correctly interpreted.

In *Holocrinus*, from the Triassic, Wagner * found a tegmen of somewhat similar conical form to that of *Apiocrinus*, composed of circular and elliptical granules and plates, of different sizes. The plates have a well-defined suture, and in the closeness of their connection, Wagner says, closely resemble the tegmen of *Apiocrinus* described by de Loriol, though in a second specimen found by him (*Op. cit.* 1891, Taf. XLIX., Figs. 2 a–b) he thinks the tegmen, in its uniform construction of small, round plates, not touching one another, resembles that of *Antedon angusticalyx* or *A. inequalis* (p. 885). It is impossible to tell from Wagner's figures where the anal opening is. P. H. Carpenter (*Op. cit.* p. 882–3), on examining the specimens, was "puzzled by the absence of any indication of ambulacral plates," though he afterward (p. 884) thought that three ambulacra might be represented by Wagner's Fig. 2 b. Professor von Koenen † afterwards made some very interesting observations upon the same specimens of *Holocrinus*. By removing some of the surrounding matrix he was able to obtain a better view of the structure. On Wagner's first specimen (*Op. cit.* 1887, Fig. 1, 1891, Fig. 2 a) he found in the deep depression lying between the base of the two broken arms and the elevated ventral sac an opening from which run two grooves to two different radii, one of which branches for the two arms. He takes the opening to be the mouth and the grooves to be ambulacral furrows. On the side of the conical elevation opposite from the mouth opening he found a second opening, which he thinks may be con-

* Ueber *Encrinus Wagneri* Ben., aus dem unteren Muschelkalk, von Jena. R. Wagner, Zeitsch. Deutsch. Geol. Gesell., 1887, XXXIX., p. 822; 1891, XLIII., pp. 879–887, (4) Taf. XLIX., Figs. 1 and 2.

† Entwicklung von *Dadocrinus gracilis* v. Buch, und *Holocrinus Wagneri* Ben., 1895. Nachr. d. K. Gesell. d. Wissensch. zu Goettingen, Heft 3, p. 283.

sidered as the anal opening. He notes the fact that the opening which he takes to be the mouth is very excentric in position.

This observation of von Koenen is of the utmost interest, as it is the first indication we have of the actual position of the mouth in the later Fistulata, and is the nearest approach to the disk structure of *Uintacrinus* that has yet been found in any fossil. Whether the supposed ambulacral furrows were covered by plates cannot be ascertained from the description. and is probably not discoverable in the specimen.

On Wagner's other specimen (*Op. cit.* 1891, Fig. 1) he also found an opening which he considers to be the anal opening.

In the same paper von Koenen gives some important information as to the disk of *Dadocrinus*. In two specimens of *D. gracilis*, somewhat crushed, he succeeded in partially freeing the tegmen, which he found entirely calcified, but which had been pliant, composed of small irregular plates, largest in the middle. This plated integument extended downward in two interradial areas as far as the second radial, and at the top terminated in a blunt point containing a small opening. From this opening the plates run downward in oblique rows, increasing rather rapidly in width until they pass into the plates in the central part of the tegmen. Of that opening he says: "The opening appears not to have been located centrally, and it may therefore well be considered as the anal opening. Of mouth and anbulacral furrows I have not been able to observe any trace."

Von Koenen thinks *Holocrinus* is to be compared with the Apiocrinidæ, among which a similar high ventral sac has been observed; while he regards *Dadocrinus* as related to older forms such as *Erisocrinus*, rather than to *Encrinus*.

Dr. Jaekel* has described a very interesting specimen of *Encrinus Carnalli*, exhibiting the tegmen, which is a thin pavement of very small plates. The mouth and ambulacral furrows are not visible, but there is a well-preserved anal tube, which rises free as a short sac, composed of finger-like folds laid together and surrounding the anal opening. These folds are not plated. What the exact position of this tube is, relatively to the centre or margin of the disk, is not disclosed, either by the description or figure. In this paper he also refers to the tegmen of *Holocrinus* as composed — especially in the middle — of relatively large plates, of irregular, rather long oval form; and he states as to *Dadocrinus*, that while its tegmen has

* Sitzungsberichte der Ges. Naturf. Freunde zu Berlin. Jahrg. 1894, Nr. 6, p. 155.

not been fully observed, yet from specimens before him he believes he can safely venture to assume that it was covered with moderately large, tolerably uniform, flat plates. He thinks that the discovery of the anal tube in *Encrinus* shows an interesting relation to the Fistulata, and that *Encrinus* differs in the structure of the tegmen markedly from *Holocrinus*, *Dadocrinus*, *Extracrinus*, and *Apiocrinus*, and all older Articulata whose tegmens are known; that it should not be united with the Fistulata; but that it is a highly specialized forerunner of the Articulata.

The Austins * give a figure of *Pentacrinus briareus* (=*P. fossilis*) from the Lias at Lyme Regis, showing a large tegmen composed of small, irregular plates. It rises in the middle into a conical protuberance, which looks as if it might be the anal tube. No indication of ambulacra is given in the figure. This is the same specimen figured by Buckland in the Bridgewater Treatise, Geology and Mineralogy, Vol. II., Pl. 51, Fig. 2. Dr. Jaekel † has described another specimen of the same species from the same locality, which differs from the Buckland specimen and all others hitherto found, in having the tegmen flattened so as to be fully visible from above, instead of being laterally compressed into a conical protuberance. Neither mouth nor ambulacral furrows are shown, though Jaekel says that the place where the mouth must have been is indicated by the position and displacement of the plates pretty near the middle of the perisome. In the size and number of plates composing the tegmen he thinks it somewhat resembles the structure of the recent *Pentacrinus naresianus*. He expresses the opinion that in this and in all other fossil tegmens the small plates close upon each other so tightly and so irregularly that the course of the ambulacral furrows cannot be fixed, and he thinks it probable that the tegmen will never be found fossil in any other condition, as otherwise the soft disk could not survive the process of decomposition, the motion of the water, and the detaching out of the matrix. This opinion of Jaekel emphasizes the extraordinary good fortune by which these delicate structures are preserved in the specimens described herein. Jaekel finds in his specimen "at the place where from analogy of the living forms one should expect to find the anus, a low pyramid somewhat sunken upon itself, composed of low, broad plates, which bear lateral projections, and on the outer side tubercles. They resemble throughout the upper plates of the proboscis of *Poteriocrinus multiplex*. But

* Monog. Rec. and Foss. Crinoidea, Pl. XII., Fig. 16.

† Sitzungsberichte der Ges. Naturf. Freunde zu Berlin. Jahrg. 1891, Nr. 1, p. 7.

their number is small, and as they diminish rapidly towards the top, we obviously have the entire proboscis." He does not state distinctly what the position of this organ is, but as he assigns the mouth to the middle of the disk, it is clear that this is excentric or lateral. Unfortunately no figure of the specimen is given.

A specimen of *Pentacrinus fossilis* from the same locality, in my collection, has the tegmen preserved. It is laterally crushed, like the Buckland specimen, but does not show the symmetric form nor central protuberance which that one does. The plates of the disk are well-defined, and join by distinct sutures. It is of very large size, and rises high up between the arms. It shows neither mouth, ambulacra, nor anal tube or opening.

The living Pentacrinidæ, which are the recent representatives of the dicyclic Inadunata, have the mouth central, and the anus excentric, notwithstanding the anal structures have ceased to have any influence upon the composition of the calyx,— there being no distinct anal plates in either cup or tegmen.

Hyocrinus, which is considered to be the living representative of the monocyclic Inadunata, has a central mouth covered by five oral plates, probably capable of opening; ambulacra with covering plates and side pieces, and anal tube excentric.

From the foregoing review of the structures of the known tegmens, it is clear that there is no similarity between the disk of *Uintacrinus* and that of any of the fossil Crinoids, except that in some Fistulata with a very large ventral sac, and in the Triassic genus *Holocrinus*, the mouth may have been excentric.

In the recent Stalked Crinoids the construction of the disk varies considerably. It may be more or less completely covered by plates,* or it may be entirely bare to the naked eye, although containing microscopic spicules at the sides of the ambulacra.† But in all of them the mouth is situated at or near the centre of the disk,‡ and the anus is excentric or marginal; and all of them have a plated ambulacral skeleton. Comparison of the figures of disks of various Pentacrinidæ in the Challenger Report on the Stalked Crinoids, on Plates XVII., XXVI., XXX., XXXII., XXXIV., XXXIX., XLIII., and L., will show how utterly different is the tegmen of *Uintacrinus* from any of them.

* Challenger Report Stalked Crinoids, p. 67. † Ibid., p. 68. ‡ Ibid., p. 68.

There remain for consideration the two great genera of the free floating Comatulæ: *Antedon* and *Actinometra*. *Antedon* has a central or subcentral mouth, with plated ambulacra, and covering plates over the food grooves usually extending throughout the arms and pinnules. Good illustrations of this are found in several figures on Plate LV. of the Challenger Report on the Stalked Crinoids, and the Report on the Comatulæ, Plates IX., XII., XXXVIII., XL., XLI. It is essentially the disk of the Pentacrinidæ.

Actinometra belongs to a type different from any other hitherto found, either recent or fossil, in the structure of its disk. Instead of having the mouth at or near the centre, as in all other known Crinoids, stalked or unstalked (with the possible exception of the highly specialized Fistulata, the complete structure of whose tegmen is not known), with the ambulacra radiating about equally to the arm bases, it is situated excentrically, either close to the margin of the disk, or at some point nearer to the centre, and the centre of the disk is occupied by the anal tube. There are a variable number of unequal ambulacra, at least two of which pass around on either side in a broad curve enclosing the anal tube. These two groove-trunks are often very long, and frequently each traverses nearly the semi-circumference of the disk. Two or more other short groove-trunks run to the lateral and anterior rays. Sometimes one or more arms are unprovided with grooves. The ambulacra are open, shallow grooves in the perisome, without plating or skeleton of any kind. P. H. Carpenter, in his well-known paper "On the genus *Actinometra*,"* says that not unfrequently the posterior divisions of the two anterior ambulacra "unite for a longer or shorter distance with the two large aboral groove-trunks, to form an open horseshoe-shaped curve bounding the anal area. The position of the anal tube in this area, and also with regard to the whole surface of the disk, varies somewhat with the position of the mouth; it is rarely, if ever, absolutely central. Its appearance differs very much, according as it is full or empty; sometimes its aperture is so completely closed as to be scarcely discernible, though the tube below is widely distended; and sometimes the aperture is patent, with its edges erected and crenate, and the tube leading to it quite shrunk and flaccid."

A characteristic example of these structures is seen in *Actinometra strota*,

* Trans. Linn. Soc., 2nd. Ser., Vol. II., p. 30.

Chall. Rep. St. Crin. Pl. LV., Fig. 2, and I reproduce Carpenter's figure of it for comparison (Pl. IV., Fig. 6).

The disk is composed of a more or less irregularly plated integument; it is in some species very completely plated, though it may be entirely membranous in the same species elsewhere.*

For further illustrations of the disk of *Actinometra* see Challenger Report on the Comatulæ, Plates LVII., LXII., LXIV., and LXVIII.

Comparison of the foregoing description and figures of *Actinometra* with those of *Uintacrinus* hereinbefore given, leaves no doubt that in all essential features the disks of the two forms are identical. The resemblance between *Actinometra* and *Uintacrinus* is not confined to the disk. Both are remarkable for the absence of any ambulacral skeleton in the arms; the food grooves in both are simply open, shallow grooves, without plated covering of any kind.

A complete calcareous plating at the sides of the ambulacra on the arms and pinnules is a constant characteristic of *Antedon* ana the Pentacrinidæ, but it does not exist in *Actinometra.* P. H. Carpenter says concerning it: † "The entire absence of side plates and covering plates in the arms and pinnules of Actinometra, even in species which have a strongly plated disk, is a very singular peculiarity, and one which I am quite unable to explain."

Besides this, there is a striking similarity in the whole aspect and structure of both arms and pinnules. The distribution of syzygies is similar. The shape and proportions of the brachials — bearing in mind that those of *Uintacrinus* are always flattened by pressure — are substantially the same. The superficial resemblance of the pinnules of *Uintacrinus* to those of *Actinometra* is remarkable. If any one will compare the pinnules as they appear in Pl. V., Fig. 1; Pl. VII., Fig. 4, with those of the various *Actinometræ* figured in the Challenger Report on the Comatulæ, on Plates LIII. to LXVIII., he cannot fail to be impressed by the great similarity. It is even more striking if one compares the pinnules of *Uintacrinus* as they lie on the slabs (Pl. VIII., Figs. C 3 and B 7), in some of the most perfect specimens, with those of alcoholic specimens of *Actinometra.* The peculiar shape, the bent and twisted positions they assume, the relative proportions in different parts of the arm, the deep serration of the proxi-

* Chall. Rep. Comatulæ. p. 276.

† Bull. Mus. Comp. Zoöl. Harvard Coll., IX., No. 4, p. 13.

mal free ossicles, are the same in both. And they are entirely different from the parallel structures in many species of *Antedon*, and the recent Pentacrinidæ, in which the pinnules are short and straight. There are some species of *Antedon*, however, which seem to have pinnules much like these.

I have before me both alcoholic and dried specimens of several of the best known species of *Actinometra*, including *Act. paucicirra*, *Act. solaris*, *Act. carinata*, *Act. meridionalis*, and notably the protean *Act. pulchella* from the West Indies, the latter being kindly sent me from the Museum of Comparative Zoölogy at Harvard College, from the collections made by Mr. Agassiz on the "Blake." In all of them the above mentioned characters are strikingly shown. In *Act. pulchella* the anal tube is large, and upon it, as well as scattered at different places on the disk, are strong, irregular plates, all embedded in the membrane, resembling pustules, and none of them suturally connected.

The unstable character of the base of *Uintacrinus* has been shown by the facts hereinbefore given. It is most interesting and significant to note that a somewhat similar instability exists in the base of *Actinometra*. The centrodorsal, which in the adult Comatulæ generally is the cirrus-bearing relic of the stem, sometimes in *Actinometra* loses its characteristic form, and becomes a mere flat plate, without any trace of cirrus-sockets, lying flush with the radials, within their circlet, and abutting by its outer sides against their inner faces (Pl. IV., Fig. 7). In *Act. paucicirra* the centrodorsal is reduced to the condition of a flat, pentagonal plate, within the ring of radials.* In these cases it might very appropriately be called a "centrale." In this species the form of the centrodorsal undergoes a remarkable series of variations, among others from pentagonal to stellate † (Pl. IV., Figs. 7, 8. 9).

In *Act. typica* and some other species ‡ the sides of the centrodorsal are resorbed, leaving clefts between it and the radials, and the remnant of the plate has such a markedly stellate appearance that a distinct genus — *Phanogenia* — was proposed by Lovén for the reception of these forms (Pl. IV., Fig. 10). In some cases the points of the basal rays are just visible outside the angles of the centrodorsal (Pl. IV., Fig. 8). These variations in the base occur only in *Actinometra*, never in *Antedon* ; but the remarkable

* Chall. Rep. Comatulæ, pp. 13–14.

† Ibid., Pl. LIV., Figs. 3–9.

‡ Ibid., Pl. LVII., Fig. 1 ; and Pl. LXV., Figs. 2–6.

variation in *Uintacrinus,* from the pentagonal centrale to the stellate infrabasal ring, may well invite comparison.

It is also to be observed that in all these varieties of *Actinometra* the angles of the centrodorsal are interradial, indicating the actual or potential existence, at some stage of growth, of infrabasals next above them.

To sum up the facts on this point, we find an identity of structure, or a striking resemblance, between *Uintacrinus* and *Actinometra* in the following particulars: —

1. Excentric position of the mouth.
2. Central position of the anus.
3. Absence of any calcified ambulacral skeleton on disk, arms, or pinnules.
4. Structure and distribution of the disk ambulacra.
5. Form and proportions of brachials, and distribution of syzygies.
6. Form, size, and general appearance of the pinnules.
7. Variable size of the anal tube.
8. Instability of the base.

SYSTEMATIC RELATIONS OF UINTACRINUS.

Mr. Bather, in his discussion of this genus,* finds its affinities to be closest with the pseudomonocyclic *Dadocrinus*, from the Trias, and thinks it was derived from that or some allied form. He says: "We have to choose between monocyclic and pseudomonocyclic forms; since, had the immediate progenitors of *Uintacrinus* well-developed infrabasals, one must suppose that these would have been retained and utilized to expand the walls of the cup, as in *Marsupites*." Whether this conclusion be correct or not, it seems to me that the argument by which it was reached will have to be reconsidered. It first essays, in comparing *Uintacrinus* with other Crinoids, to clear away secondary, or non-essential features, such as the unstalked or free-swimming character, by which H. A. Nicholson and P. H. Carpenter had — erroneously, as Mr. Bather thinks — placed it in a family with *Marsupites*. This character he believes to be due rather to similarity of environment than to similarity of descent, and he takes the resemblance to be physi-

* Proc. Zoöl. Soc. London, 1895, pp. 999 *et seq.*

ological, not morphological. Of like secondary and non-essential nature he considers the thinness of the test (although on p. 1000 he says that the thickness of the cup-plates of *Apiocrinus* forbids us to infer any direct affinity with *Uintacrinus*), the large size of the calycal cavity, the flexibility of both test and arms, in which these forms have come to resemble one another. The essential dissimilarity, by which the secondary character of the foregoing resemblances is made more apparent, he considers to be that while "*Marsupites* has radials, basals, and infrabasals, *Uintacrinus* has no infrabasals, but in addition to its basals and radials, has brachials, interbrachials . . . all helping to compose its dorsal cup."

Without disputing the contention that the characters thus considered as secondary may be due solely to environment, I wish to point out that the reasoning based upon the assumed "essential characters" of *Uintacrinus* loses some of its force when it is discovered that in one of those essentials — the one to which Mr. Bather attaches the greatest importance — the calyx of *Marsupites* and that of one form of *Uintacrinus*, from the radials down, are identical; that for this reason the morphological dissimilarity between *Marsupites* and *Uintacrinus* is not so complete as it before appeared; and that the derivation of *Uintacrinus* from any given form cannot now be predicated upon the possession of "5 basals and 5 radials," which were considered among the essentials of structure pertaining to *Uintacrinus*. It must also be noted, though Mr. Bather did not base any argument upon this point, that *Uintacrinus* cannot now be considered as a pseudomonocyclic form, in the sense that the centrale might be the fused infrabasals; for, as already shown, the two forms of *Uintacrinus* are either distinctly monocyclic or distinctly dicyclic. I do not wish to be understood as contending that *Marsupites* and *Uintacrinus* are closely related, — on the contrary, I consider them widely different, and I agree with Bather that Carpenter's and Nicholson's reference of them to one family was erroneous. While *Marsupites* has, from the radials down, the calycal structure of the dicyclic *Uintacrinus*, the two really belong to totally different types. *Marsupites* is an Inadunate Crinoid. Its brachials, though sometimes loosely united by small plates, are not incorporated into the dorsal cup; its radial facets are very narrow, not occupying half the margin of the plate, thus making the arms perfectly distinct from the dorsal cup. *Uintacrinus* is not an Inadunate Crinoid; but on the contrary it has brachials and pinnules deeply incorporated into the dorsal cup by means of an interbrachial system on a par with that of the

most highly developed Camerata; and its first brachial occupies the entire width of the radial. It differs from *Marsupites* as *Strotocrinus* differs from *Cyathocrinus*, and these differences are sufficient to refer them to different sub-orders.

Among the many remarkable things about this strange form, none is more striking than the extraordinary way in which *Uintacrinus* combines several characters which belong to the great primary divisions of the Crinoids: —

Camerata. In the manner in which the proximal pinnules are fixed by the growth of interbrachial plates, we have a repetition of the peculiarities of certain highly typical Camerate genera. In forms like *Strotocrinus*, *Teleiocrinus*, etc., where the side arms, branching alternately from each successive brachial, may be considered as modified pinnules, we find the lower ones fixed and incorporated into the calyx * by sutural connection with interbrachials, intersecundibrachs, and even intertertibrachs. This occurs also in *Melocrinus*. † In *Glyptocrinus* and *Reteocrinus*, however, two of the oldest genera, we have the lower pinnules themselves fixed in a similar manner.‡ If any one will compare the disposition of the plates in the interbrachial system of *Glyptocrinus Dyeri*, and the mode of fixation of its lower pinnules, with the corresponding parts in *Uintacrinus*, he will be compelled to admit that in this feature of their organization no two Crinoids could be structurally more nearly alike than these. The large size of the body cavity, resulting from the great development of the interbrachial plates, is also a character in which it resembles the Camerata, and the Flexibilia as well, and in this respect it shows a marked departure from the Inadunata.

Flexibilia (Articulata, *sensu* W. & Sp). If we consider such genera as *Sagenocrinus*, from the Silurian, and *Taxocrinus* from the Silurian to the Carboniferous, we will find that the interbrachial systems of these forms are substantially the same as that of *Uintacrinus*, giving rise to a similar enlargement of the visceral cavity. The fixed pinnules are wanting here, because there are no pinnules in the Impinnata division of this group; but otherwise the interbrachial and intersecundibrach spaces are filled with supplementary plates in the same way, so as to produce a greatly expanded, rotund calyx; and they also increase in number with growth in a similar

* Mon. Crinoidea Camerata, Pl. LXV., Figs. 1a, 1c, 2a. † Ibid., Pl. XXIII., Fig. 1.

‡ Ibid., p. 84, Pl. XIX., Fig. 1; XX., Fig. 1.

way. Besides this, we have most conspicuously exhibited in *Uintacrinus* the pliant test of the Flexibilia.

Inadunata. Mr. Bather traces in *Uintacrinus* a direct morphological resemblance to *Dadocrinus*, of this group. In the essentials of structure upon which the great groups of Camerata, Inadunata, and Flexibilia have been distinguished, *Uintacrinus* seems to me far more widely separated from this group than from the others. It has an undoubted similarity in the arms and pinnules, and in the arrangement of syzygies, to *Dadocrinus*. But aside from these it possesses none of the characters which distinguish the Inadunata. The absolute and deep incorporation of its brachials and fixed pinnules into the calyx walls, is a character fundamentally inconsistent with any position under the Inadunata. It is, of course, possible to imagine, as suggested by him, that a gradual exaggeration of the features of *Dadocrinus*, and loss of the stem, might have produced *Uintacrinus*, just as the gradual addition of interbrachials to a *Cyathocrinus* would produce a Camerate Crinoid; and this means nothing less than the transition, phylogenetically, from one primary group to another. It may be possible that *Dadocrinus*, or some allied form, represents the line through which the characters of Camerata, Flexibilia, and Inadunata came to be combined in a convergent type such as this is. But if so, the line must include the Comatulæ, or at least the genus *Actinometra*, which has all the essential characters of *Uintacrinus* except the interbrachials.

Monocyclica and Dicyclica. *Uintacrinus* has both forms of base. If these are the primordial characters by which all the Crinoids are to be divided into two sub-classes, then the sole distinctive characters of each of them are found converging in this Cretaceous species.

It must be evident that the line of derivation of *Uintacrinus* will have to be considered in connection with the Comatulæ. Whatever its ancestry may have been, it is quite plain that one of its near relatives was *Actinometra*. The fossil Comatulæ are said to range back to the middle Lias, and are fairly abundant in the Cretaceous. According to Carpenter* *Actinometra* occurs in the Lower Oolites of both France and England, and also in the Corallian of the Jura, and the Gault of the English Cretaceous.

* Chall. Rep. Comat., p. 37.

Uintacrinus certainly represents a parallel development. In addition to the free-floating habit, it has the disk of one of the Comatulid genera, such as no other Crinoid is known to have, and also its open ambulacra, arms, and pinnules. Furthermore, *Actinometra* is now generally considered to be a dicyclic — or rather pseudomonocyclic, — or "cryptodicyclic" — Crinoid, although infrabasals have never been seen in it. Mr. Bather classifies it among the Dicyclica in the Lankester Zoölogy. It is therefore a legitimate assumption that at some stage of its larval development it possessed infrabasals, and also a stem (which indeed we know it had), with the top columnal of which they fused, and which disappeared, leaving this top columnal as a relic — the so-called centrodorsal. In what order these conditions occurred, of course we do not know; but as a consequence of them it follows that at some period, or successive periods, of its growth, the base of *Actinometra* contained the same — or equivalent — elements as *Uintacrinus*. Obliterate the interbrachial system of *Uintacrinus*, and we would have some stage of *Actinometra*; conversely, by adding the interbrachials, and supposing some larval stage or stages of the base of *Actinometra* to become persistent, we would produce *Uintacrinus*.

And this suggests that it would be a most important thing if somebody could work out the life history of *Actinometra*, as W. B. Carpenter, Wyville Thomson, and Bury have done for *Antedon*. There are several species which seem to be sufficiently littoral in habitat to make this practicable. The "pentacrinoid" stage of *Act. meridionalis* has been seen. It was brought up by the "Blake," and described by P. H. Carpenter* substantially as follows: —

Actinometra meridionalis: Two pentacrinoids were found among the "Blake" collections, one at about the stage represented at Fig. 1 B, Pl. XXXIX., of W. B. Carpenter's work on *Antedon rosacea*, and the other by Fig. 1 C of the same plate. The centrodorsal is scarcely larger than the stem joints immediately below it; five of these are short and discoidal, and the next much elongated.†

The displacement of the mouth in *Actinometra* from the central position which it occupies in the tegmen of the Crinoids generally, represents a

* Bull. Mus. Comp. Zoöl., IX., No. 4, p. 14.
† See also Agassiz's Seaside Studies, p. 121.

most remarkable modification. It is connected with an arrangement of the gut which is different from that of all other recent Crinoids, and which has not hitherto been known to have a parallel among fossil forms. The latest description of this is by Mr. Bather in the Lankester Zoölogy, Pt. III., p. 136, as follows: "In most recent crinoids this [the gut] makes a simple dextral coil around the thecal cavity, from central mouth to excentric anus. The mouth may be slightly shifted anteriorly by increase in size of the anus, or by the anal tube coming to occupy the centre of the tegmen, as in *Batocrinus*, or even to pass beyond it towards the anterior margin, as in *Siphonocrinus*. But the mouth remains in the axis of the coil, and such forms are called 'endocyclic.' In *Actinometra* the gut winds in the same way, but instead of issuing immediately the first coil is completed, it continues to coil, not however around the axis of the mouth but around the axis of the anus. The mouth, with its annular accompaniments, therefore lies between the outer coil and the next one, and not in the axis of the coil; such a form is called 'exocyclic.'"

A fact in phylogeny which might have brought about a change like this is the great specialization of the ventral sac among the Inadunata Fistulata, already referred to, especially those of the family Poteriocrinidæ (W. & Sp.). This was accomplished through an enormous upward expansion of the posterior interradius, which must have been accompanied by some functional change, for the anus is not carried upward with it, but remains at some point below the summit, either near the base of the sac,* or half way up,† or discharging out of a lateral branch or spout.‡ In all these cases the anus remains on the anterior side of this protuberant sac, towards the mouth. While thus bringing the part of the gut leading to the anus to a vertical position towards the central part of the tegmen, it seems probable that the mouth was to some extent pushed from the centre towards the margin. The precise effect upon the mouth is not known, for no one has ever been able to identify its position in these forms, either from internal structure or the disposition of the plates externally; although we have sacrificed a number of fine specimens in the effort to do so.

In the Encrinidæ, which are the successors of the Poteriocrinidæ, the extreme fistulate character was lost, and the ventral sac became reduced again to an insignificant protuberance. What its exact position was, is not

* Mon. Crin. Cam., Pl. VII., Fig. *a*. † Ibid., Pl. VII., Figs. 2 *a*, 3, 4, 7.
‡ Ibid., Pl. VII., Fig. 9.

known. The mouth might have retained its marginal position, or it might, with the removal of the cause, have returned to its original central position. In favor of the latter view is the fact that the recent Pentacrinidæ, which may be considered to be the successors of the Encrinidæ, have no trace of this structure, but have the mouth strictly central, and the gut has but a single coil. In favor of the former is the case of *Holocrinus*.

Whatever its origin, the coil of the gut in *Actinometra* is a structure, as Bather says, which is doubly peculiar, and undoubtedly is a morphological modification of much importance, — although he attaches no importance to it in classification. And there can be no doubt that the same structure existed in *Uintacrinus*.

The relations of *Uintacrinus* will probably be a subject of discussion for some time to come. Neumayr, von Zittel, and P. H. Carpenter have classed it with the Flexibilia. Bather believes its relations to be with the dicyclic Inadunata. Jaekel places it provisionally among the Camerata, along with the dicyclic Rhodocrinidæ. There are difficulties attending each of these theories, and more or less strong reasons can also be adduced for each. Mesozoic Crinoids are so rare, and the gaps between them and their Palæozoic predecessors so wide, that comparisons are difficult, and lines of derivation impossible to trace with certainty. All these views, however, will have to be reconsidered in the face of the new and remarkable characters disclosed by the present material. In the flexibility of the calyx and arms, the possession of an interbrachial system, the large size of the visceral cavity, the distinctness of the axial canal, and the dicyclic base in one form, *Uintacrinus* certainly exhibits a morphological resemblance to some of the Flexibilia which is of striking significance.

The general absence of true pinnules and of syzygial union in the arms of the Flexibilia Impinnata is undoubtedly an argument against its relation to that branch of this group. But this would not apply to the Pinnata, which go back to the Jurassic and perhaps to the Trias. It may be true, as remarked by Mr. Bather, that none of the known Flexibilia — by which I suppose he means only the Impinnata — show a predilection for a free mode of life, as do some of the Inadunata. But I would suggest that there was a strong tendency among many of the Flexibilia of that branch for the stem to break off, leaving the top columnal attached to

the calyx, or fused with the infrabasals; *e. g.*, the Ichthyocrinidæ.* This results from the fact that generally in this group, so far as known, the stem did not increase by the introduction of new columnals at the extreme proximal end, but by their introduction next below it,† — the top columnal remaining as a persistent proximale. Hence the stem would be most easily detached at that point, and the top columnal would remain.

A similar result is produced, either by atrophy or absorption of the stem, or by its breaking off just below the proximale, in *Millericrinus Pratti.* ‡ May not *Uintacrinus*, with its centrale a probable relic of the stem, represent that stage phylogenetically in which the stem has been permanently lost at that point, as is actually the case with *Actinometra* and the other Comatulæ? It seems to me that the few cases in which a free-floating habit was developed among the Inadunata — such as *Agassizocrinus*, in which the whole stem disappears, and the top columnal does not remain to form a centrodorsal or centrale — are by no means so suggestive of derivation as the facts just mentioned. Mr. Bather, in his new classification in the Lankester Zoölogy, Pt. III., Chap. XI., p. 182, places *Dadocrinus* among the Inadunata, and in the family Pentacrinidæ. This family, so far as known, has a central mouth, and a calcified ambulacral skeleton. Then he places *Actinometra* among the Flexibilia. If this be correct, then *a fortiori* why should not *Uintacrinus*, with its excentric mouth and open ambulacra, in addition to its pliant test, separate axial canal, extensively developed interbrachial system, and unstable base, go likewise with the Flexibilia, and not with the Inadunata?

Of course it is possible, as Bather suggests, that the Pinnata were derived from the Mesozoic Inadunata, and not from the Impinnata. The pinnulate feature of the Pinnata seems to be the chief reason for this suggestion. It seems to me that if the possession of pinnules would not remove a genus from the Cyathocrinoidea division of the Inadunata § there is no controlling reason for supposing that a pinnulate may not be derived from a pinnuleless form in course of geological time. The Impinnata have about as ancient a lineage as the Inadunata, for they go back to the Lower Silurian. It is also known now that they come down at least to the Coal

* Wachsmuth and Springer, Mon. Crin. Cam., Pl. II., Fig. 4 *b;* Pl. VI., Fig. 11.

† Ibid., pp. 39, 40, 152.

‡ P. H. Carpenter. On Some New or Little Known Jurassic Crinoids. Quart. Jour. Geol. Soc., Feb. 1882, pp. 29–38, Pl. I.

§ Lankester Zoölogy, Pt. III., Ch. XI., p. 172.

Measures, as I have a specimen of *Ichthyocrinus,* or some closely allied genus, from those beds in Kansas, — which brings the Impinnata somewhat nearer geologically to the Liassic Comatulæ than was before known.

Wherever it may belong, and whatever its line of descent, there is no doubt that *Uintacrinus* is both a protean and convergent form more remarkable than any we have hitherto encountered among the Crinoids. Along with great variability and instability in the base and interbrachial regions, it combines: —

The interbrachial system and fixed pinnules of the Camerata.

The pliant test of the Flexibilia.

The large visceral cavity of both these.

The exocyclic disk and open ambulacra, and the arms, pinnules, and syzygies of *Actinometra.*

The free-floating character of the Comatulæ.

The dicyclic base of the Dicyclica.

The monocyclic base of the Monocyclica.

SPECIFIC RELATIONS OF SPECIMENS FROM LOCALITY NO. 2.

The colony of small specimens found at Locality No. 2 is a very interesting occurrence. As already stated, the principal material secured therefrom is the fine slab in the Kansas University Museum at Lawrence. Through the courtesy of Chancellor F. H. Snow, and Dr. S. W. Williston, of that institution, I have had full liberty to examine and study this material, and, in addition to this, I am indebted to them for some well-preserved specimens of this form for the illustration of this paper. I acknowledge my deep obligation to these gentlemen for the aids thus generously afforded me.

Only a portion of the colony was recovered, the greater part of it having been destroyed with the erosion of the ravine. As flattened out in the fossil state, it was evidently about eight feet in diameter, and the specimens were massed together and consolidated into a thin plate, as at Locality No. 1. In the portion preserved there are about 550 calices visible on the lower

side. They are not at all of uniform size, but vary all the way from 6 mm. to 37 mm. in width, in about the following proportions numerically: —

Under 12 mm.	150 specimens.
Between 12 and 25 mm. . . .	350 "
From 25 to 37 mm.	50 "

Hence the difference in size between these and the specimens from Locality No. 1 is not constant. The largest from Locality No. 2 are larger than the smallest from Locality No. 1; but the prevailing size is far below that of the specimens from the latter locality. By far the greater number — 75 per cent at least — are lying with the base exposed, showing that they were clinging close together by the arms; but of these at least 80 per cent have had the basal plates rubbed off, either by weathering or too severe use of the brush in cleaning. The reason why so many of them have the base exposed is no doubt their small size and the shortness of their arms, by which, in clinging together, the calices were drawn up and held closely against the exterior of the floating mass. The arms were in no case visible to the extremities, but in the smaller specimens were probably not over 10 cm. in length. A large majority of this colony belong to Form D. Out of 99 specimens in which the base is distinguishable, there are: —

Monocyclic	24
Dicyclic	75

As at Locality No. 1, the difference in this respect does not appear to be correlated with any other. Some of the smallest are monocyclic and some of the largest dicyclic, and *vice versa*.

Many of these specimens were very small Crinoids. Allowing for the flattening, the smallest of them in life was only about 4 mm. in diameter at the widest part of the calyx, or about the size of an average *Pisocrinus*; whereas a large adult from Locality No. 1 was 50 mm., or two inches, in diameter in life.

The Crinoids of this colony have superficially an aspect somewhat different from those of the other localities. This is partly due to the fact that the brachials are here proportionally more prominent, and the interbrachial areas less conspicuous; and also that the basal and radial circlets are proportionally larger in the small ones. An average of a number of

specimens gives the following result on the last point, in percentage of total width of calyx: —

Specimens 35 mm. and less . . . BB 16% . . . RR 36%
Specimens 50 mm. and more . . . BB 12% . . . RR 27%

But these, and the other differences to be noted, are for the most part precisely the ones which result from differences in age.

I have come to the conclusion that all these small specimens from Locality No. 2 are the young of *U. socialis.* This opinion is based on the following reasons: —

In the first place, their calyx plates are extremely thin. In a large proportion of the specimens from Locality No. 2 the plates of the plumpest specimens are eroded on the convex portions, and in many of them altogether. In several of the young ones from Locality No. 1, and of those from Locality No. 2 as well, the plates of the interbrachial areas are so thin that the black carbonaceous lining shines through them at the sutures. In the second place, the arms have the undeniable characteristics of the young. It is a fact evidenced by numerous observations that in Palæozoic species the brachials of young individuals are proportionally much more elongate than those of the adult. This is well shown by *Platycrinus huntsvillæ,* a species which is found in various stages of growth from the very youngest, with uniserial, zigzag arms, to full grown ones, with arms biserial down to the bifurcation. The following table of measurements was taken from a series of eleven well-preserved specimens, ranging in

TABLE C.

Measurements of *Platycrinus huntsvillæ.*

Specimen.	Height of Crown.	Height of Calyx.	Diameter of Calyx.	Brachials.	
				Length.	Width.
1	10 mm.	2.50	4.0	.50	.50
2	12	3.00	5.0	.52	.62
3	17	5.00	6.0	.57	.75
4	22	6.00	7.0	.55	1.00
5	25	6.00	8.0	.55	1.25
6	28	7.00	9.5	.55	1.25
7	31	9.00	12.0	.55	1.25
8	32	9.00	11.0	.55	1.50
9	34	10.00	13.0	.55	1.50
10	44	15.00	15.0	.75	1.75
11	50	15.00	17.0	.62	1.75

height of calyx and arms complete from the maximum adult size of 50 mm. down to 10 mm.

Here, as elsewhere, the length of the brachials changes but little with growth, but the enlargement takes place transversely, — the width of the brachial increasing with a fairly regular progression, — so that the ratio of width to length increases from $\frac{1}{1}$ in the youngest specimen to $\frac{3}{1}$ in the oldest.

Similar measurements on a series of *Forbesiocrinus* will be found later on, showing the same result (Table E).

Dr. W. B. Carpenter, in his account of the Development of *Antedon rosacea*,* says that in the young *Antedon* the form and proportions of the arm segments vary widely in different parts of the arm; — "their length being four or five times their diameter near its extremity; less than twice their diameter about its middle; less than half their diameter near its base; this diversity almost entirely results from the progressive increase in *diameter*, which shows itself in the segments as we pass from the extremity toward the base, the absolute length of the segments being nearly the same throughout." The same rule obtains in *Uintacrinus*, as is shown by the measurements of brachials in different parts of several arms already given. That is to say, the newer the segment the longer it is in proportion to its diameter or width, and the relative as well as absolute increase in diameter in parts of the arm of the same individual is due to age. We would confidently expect to find the same rule applying as between corresponding brachials in young and adult specimens, and we find the fact stated accordingly by Dr. Carpenter on page 734 of the same paper: "The average length of the basal segments of the arms at this (early) stage of Pentacrinoid life is about .007 inch, and their diameter about .003 inch; whilst in the adult *Antedon* their length averages about .03 inch, and their diameter about .07."

I have applied this test to a number of specimens of *Uintacrinus* from both Localities 1 and 2, with the results shown by the subjoined table of measurements. This gives the width of the calyx at about the top of the first intersecundibrachs, and the length and width of the brachials — or arm segments of W. B. Carpenter — at about the 10th secundibrach. As the adjacent brachials are not always of uniform length, I have in measuring the length taken the average of several successive plates. All

* Philos. Trans. 1866, p. 717.

TABLE D.

Proportions of Brachials in various Specimens.

Specimen.			Width of Calyx.	Brachials at about 10th IIBr.	
				Length.	Width.
Loc. 2.	K	8	6.25	.75	.75
	"	30	7.50	.75	.75
	"	26	7.50	.75	.87
	"	78	7.50	.62	.75
	"	79	7.50	.62	.75
		134	8.75	.50	.50
		131	9.00	.75	.75
	K	31	10.00	.75	1.00
	"	70	10.00	.75	1.25
	"	24	12.50	.75	1.00
	"	69	15.00	.75	1.25
	"	49	15.00	.75	1.50
		126	15.00	1.00	1.00
		124	16.00	1.00	1.25
	K	75	17.50	1.00	1.75
	"	7	17.50	1.12	1.25
	"	4	18.50	.75	1.50
	"	77	18.50	1.00	1.75
	"	50	18.50	1.00	1.75
	"	58	18.50	1.25	2.50
	"	22	18.50	1.00	1.12
	"	28	20.00	1.12	2.00
	"	35	20.00	.87	1.50
	"	65	21.00	1.00	2.00
	"	13	21.00	1.12	1.75
	"	39	23.00	.75	1.50
	"	74	23.00	1.00	2.25
	"	10	26.00	1.00	2.50
	"	25	29.00	1.12	2.75
	"	56	31.00	1.25	2.50
Loc. 1.		XX *b*	16.00	.75	1.50
		XX *a*	22.00	1.00	2.00
		XVIII *a*	19.00	.75	2.00
		VIII *b*	27.00	1.00	2.25
		78 *a*	25.00	1.00	2.25
		I *kk*	27.00	1.00	2.50
		XIX *a*	30.00	1.25	3.00
		XII *t*	30.00	1.25	3.00
		78 *b*	31.00	1.00	3.50
Loc. 3.		180	31.00	1.25	3.50
Loc. 1.		I *ee*	38.00	1.00	3.50
		XII *m*	37.00	1.50	4.50
		VII *a*	38.00	1.25	4.25
		3	39.00	1.22	3.75
		I *h*	42.00	1.25	5.25
		IX *e*	45.00	1.25	4.50
		VII *b*	46.00	1.50	6.25
		VII *c*	48.00	1.50	6.25
		XII *r*	50.00	1.50	5.75
		XII *h*	54.00	1.50	6.75
		VII *g*	60.00	1.75	8.00
		I *xx*	65.00	1.75	8.75
		43	67.00	1.50	8.00
		IX *a*	74.00	1.50	7.25

Specimen.	Brachials at about 10th IIBr.		
	Length.	Width.	
Average of specimens 25 mm. or less	.93	1.45	$\frac{1}{2}$
" " " 25 to 37 mm.	1.17	3.22	$\frac{1}{3}$
" " " 37 to 50 "	1.32	5.20	$\frac{1}{4}$
" " " 50 mm. and up	1.60	7.75	$\frac{1}{5}$
Actinometra paucicirra . . young	.75	.82	$\frac{1}{1}$
" " . . . adult	1.25	2.75	$\frac{1}{2}$
" *solaris* . . . young	.75	1.00	$\frac{1}{1}$
" " . . . . adult	1.37	2.50	$\frac{1}{2}$
Antedon rosacea . . . . young	.0175	.0075	$\frac{2}{1}$
" " . . . . . adult	.75	1.75	$\frac{1}{2}$

the specimens being more or less flattened by pressure, we can only give the relative size of the calyx by taking its width in its present condition; the diameter of the calyx in life may be taken as approximately 60 per cent of the width thus given.

These measurements show that in their arm structure the specimens from Locality No. 2, and the small ones from Locality No. 1 as well, exhibit most decidedly the characters of the young individuals. While, as in the different parts of the arm of the young *Antedon*, the absolute length of the brachials does not differ so very much in the different specimens, the increase in width is very marked as the size of the specimens increases. In the smallest specimens from Locality No. 2 the length of the brachial is about equal to its width. Taking the average, it appears that in specimens 25 mm. wide or less, the width is less than twice the length; in those from 25 to 37 mm. it is about three times; in those from 37 to 50 mm., about four times; while in those of maximum size — 50 mm. and over — the brachial is about five times as wide as long.

From the smallest to the largest specimens the brachials increase in length only from .50 mm. to 1.75 mm., while in width they increase from .75 mm. to 8 mm. We have thus a progressive increase in width of the arm which is remarkable for its uniformity in relation to the size of the calyx. Such increase is substantially parallel to that which takes place from the young to the adult *Antedon*. It must be remembered that the young *Antedons* measured by W. B. Carpenter were in the pentacrinoid stage, much younger, relatively, than our specimens, and therefore the width of the arm-segments was proportionally less. But the increase in

the ratio of width to length from the young to the adult *Antedon* — from $\frac{75}{175}$ to $\frac{175}{75}$ — is about the same as in our specimens, viz., about five times.

An interesting illustration of these characteristics of the arm may be seen in the photograph of specimen No. 233 (Pl. VII., Fig. 4), which shows, lying side by side, parts of six arms, belonging to as many different individuals, of sizes ranging quite gradually from almost the maximum to the minimum. The large arm begins at about the 25th brachial, and the smallest one is almost at the distal end. The others are from median or upper portions of the arm. Measurements of the brachials in these arm fragments, taken in the order of their size beginning with the smallest, are as follows: —

No. 1	length	.50 mm. . . .	width	.50 mm.
" 2	"	.75 " . . .	"	1.10 "
" 3	"	1.00 " . . .	"	1.50 "
" 4	"	1.15 " . . .	"	2.00 "
" 5	"	1.25 " . . .	"	2.25 "
" 6	"	1.45 " . . .	"	4.50 "

This gives about the same relative proportion as the data heretofore given from different parts of the same arm. A similar result may be arrived at by comparison of the brachials of specimens D 6, B 1, C 4, and D 4, on the photographic Plate VIII.

These specimens from Locality No. 2 also show, at first glance, a marked difference from the others in the number of plates in the interbrachial spaces. A large proportion of them have but a few interbrachials, 5 or 6 plates being the rule among the smaller ones, — thus giving the arrangement of *U. westfalicus*, — whereas among the specimens from Locality No. 1 the number is generally much larger. The variation in this character, however, among the specimens from both localities is so great, that I do not see how any specific distinction can be based upon it. If *U. westfalicus* could be upheld as a distinct species, on account of the arrangement of its interbrachial areas, then it might be that the smaller Locality No. 2 specimens, although undoubtedly young individuals, are not the young of *U. socialis*. In that case, with our present knowledge, we should have to call them the young of *U. westfalicus*.

I do not think it will be necessary to consider this contingency, for reasons that will shortly follow. For an attentive comparison of the facts exhibited by all the specimens will show that the variation in the

number of interbrachial plates is also an individual one, due to growth. As these are supplementary plates, whose office is to fill up the space required for the expansion of the calyx, we should expect to find that, as a general rule, their number increased with age, — and such proves to be the case. This will be more fully considered under the next head.

RELATIONS OF U. WESTFALICUS TO THE AMERICAN SPECIMENS.

The only differences that have hitherto been pointed out between *U. westfalicus* and *U. socialis* are: —

1. That the brachials in *U. socialis* are decidedly broader than in *U. westfalicus.*
2. That the interbrachials differ in number and arrangement.

As to the first, by referring to Table D *supra*, containing measurements of brachials in various individuals, it will be seen that this difference may be readily traced to difference in age of the individual. The specimen figured by Schlueter * would be of about the medium size of *U. socialis* as found by me. The calyx is about 41 mm. wide, and the brachials at about the 10th IIBr. are 5 mm. wide, and about 1.37 mm. long; or the width is about three times the length (Pl. III., Fig. 7). This is about the proportion of medium-sized specimens of *U. socialis*, — as, for instance, my No. 3 (Pl. V., Fig. 2), which with a calyx 39 mm. wide has the corresponding brachials 3.75 mm. wide and 1.22 mm. long; while if the comparison were made with young specimens (Pl. V., Fig. 4), it would appear that the brachials of *U. westfalicus* are much the broadest of the two.

The second point requires careful consideration, as it has been chiefly relied upon by Schlueter and the authors subsequent to him to distinguish the two species. Neither Grinnell nor Schlueter seem to have understood the nature of the fixed pinnules, for they treat the plates composing them as "interradials" and "interaxillaries," without distinguishing them from the plates lying below them, which properly belong to those categories. Condensing Schlueter's description as to these plates, it amounts to this: —

* Zeitsch. d. Deutsch. Geol. Gesel., XXX., Taf. IV., Fig. 1.

The interradials (interbrachials of current terminology) consist of five large plates (sometimes six), which generally project like an arched shield; these vary in outline and position in the different interradii. The interdistichals (intersecundibrachs) are two, lying one above the other.

Comparing the two species, he says: —

"In form and size the two crinoids show no other differences than that in *U. socialis* the interradii do not project. . . . The most important observable difference on which a specific distinction can be based lies in the variation of the intermediate plates," — *i. e.* the interradial and interaxillary fields.*

Clark, in discussing the relations of the two species, says: —

"In the number and arrangement of the interradials the most marked difference is manifested. In *U. socialis* seven interradial plates encircle the eighth, or eighth and ninth, as the case may be; while in *U. westfalicus* the interradials are five in number, all of which come in contact with plates of other areas." †

Bather says: "It is chiefly in the arrangement of the interradial plates that this species differs from *U. socialis*." ‡

With regard to the projection or swelling of the "interradial" areas, this occurs occasionally among my specimens. No. 45 (Pl. III., Fig. 2) shows it very conspicuously, and it is found in about ten others. On Slab I there is a specimen with arched interradii, in which two of them contain but a single large plate, formed by the anchylosis of five or six original plates.

It is not difficult to pick out from among the specimens of *U. socialis* in this collection some which are in all essential points almost the exact counterparts of Schlueter's specimen. No. 242 (Pl. III., Fig. 6), in size of calyx, proportions of brachials, number of interbrachials and intersecundibrachs, is substantially identical with it, and No. II *b* and 247 also, except in the base, as the following comparison shows: —

	Calyx.	iBr.	iIIBr.	Base.
U. westfalicus .	41 mm.	5–5	2	M
No. 242 . . .	44 "	5–5	2–1	M
" II *b* . . .	50 "	5–5	2–	D
" 247 . . .	41 "	3–5	2–3	D

The difference in shape of the calyx is incidental, due to the manner of compression.

* Op. cit. p. 61. † Op. cit. p. 23. ‡ Op. cit. p. 977.

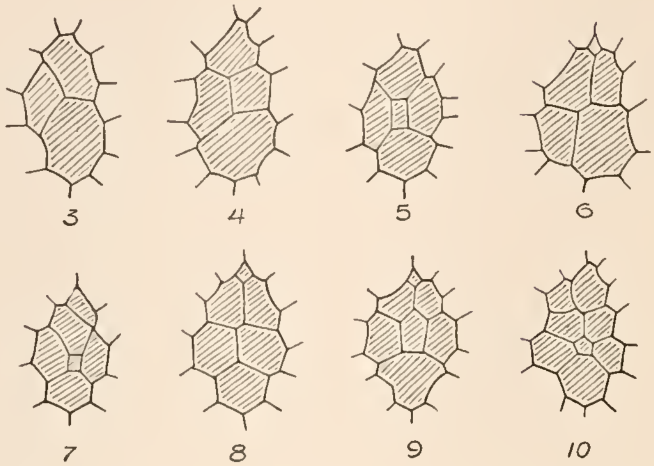
I have already shown that the statement of Clark as to the regularity in the arrangement of the interbrachials of *U. socialis* into a ring of plates enclosing one or two others does not hold good when large collections are examined. There are many specimens of adult *U. socialis* which have 5, 6, or 7 interbrachials, in all of which — and sometimes in those with 8 or 9 — all the plates "come in contact with plates of other areas," and there is no enclosed plate (Pl. V., Fig. 6; Pl. VI., Fig. 1; Pl. III., Fig. 6). And in the young of Locality No. 2 this is the most common form. The variation in the number and arrangement of the interbrachial plates is enormous. The number among adults ranges from 6 — rarely 5, 4, or 3 — (Pl. III., Fig. 6; Pl. V., Fig. 5; Pl. VI., Fig. 1) to 22 or 23 (Pl. VI., Figs. 5 and 6); and among the young from 5 — rarely 3 or 4 — to 9 or 10 (Pl. III., Figs. 3, 4, 5; Pl. V., Figs. 3, 4). Generally there is one interbrachial abutting on the radials in the first range; but sometimes there are two (Pl. VI., Fig. 5), or three (Pl. VI., Fig. 2) plates in the first range. Sometimes, though rarely, the first interbrachial passes down between the radials and meets the basals, as in the Rhodocrinidæ. Cases of this kind are shown by Pl. VI., Fig. 5, and Pl. V., Fig. 4, where the first plate of one interradius rests upon a truncated basal. If our knowledge of the genus were derived from either of these specimens alone, we would not hesitate to put an anal plate in the diagnosis. In another specimen, however, the same thing occurs in three interradii (Pl. VI., Fig. 6). These are exceptional cases, and represent only sporadic variations.*

The variation in the interbrachial spaces is not only exhibited between different individuals, but is equally conspicuous between different areas of the same individual (Pl. V., Fig. 6). Indeed it is rather rare to find among the adults a specimen showing three or more interradii in which the number of plates is the same in all. It is more uniform among the young, as we should expect would be the case. The form and proportions of the plates also differ very materially, both in the same and between different specimens. In some areas there are a large number of small plates (Pl. VI., Fig. 2), and in others an equivalent space is filled by a few very large plates (Pl. VI., Fig. 1).

The accompanying text figures of interbrachial areas from some of the

* It is interesting to note that an irregularity of this kind is found among the Ichthyocrinidæ. In certain *Taxocrini* exceptionally, and in one species as a rule, a plate is interposed between the radials, and touches the basal in two or more interradii.

younger specimens will give a good idea of the mode of increase, both by upward growth and by intercalation, through which these variations are produced.

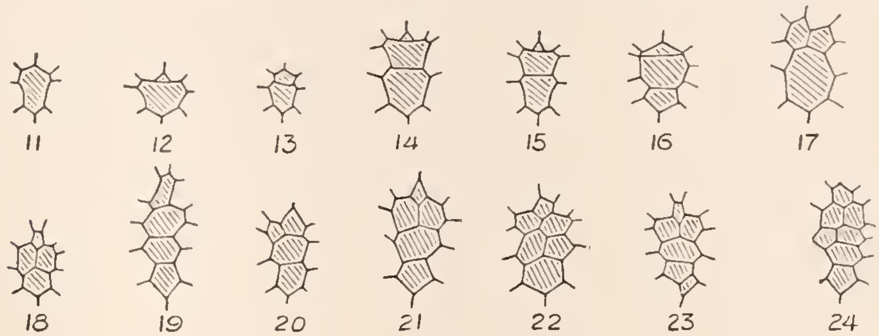


Simpler forms of interbrachial areas, showing mode of increase of plates by intercalation and upward growth. 3 and 4 are from specimen LVIII *b*; 5 and 7 from a specimen in the Kansas University; 6, 8, and 9 are from LVIII *f*; 10 is from No. 70.

If we had still younger stages of growth we should no doubt find areas with only one and two plates, just as we now find in the intersecundibrach spaces. As it is, our lowest number — Fig. 3 — is three good-sized plates, evidently developed from two in vertical succession — the third being pushed in from the side, opposite the suture between them. In Fig. 4 a fourth plate has been added, either from two, by lateral intercalation opposite the suture from each side, or from three, by addition of a cuneate plate above. In Fig. 5 a fifth plate is intercalated in the middle of the previous four, while in Fig. 6 it is added at the top. In a similar manner a sixth, seventh, and eighth plate is inserted, either at the top, in the middle, or both, — Figs. 7, 8, 9, and 10, where the young plates are seen just beginning to form. By a continuation of this process the more complex spaces are filled, up to as many as 21 or 22 plates (Pl. VI., Fig. 5). Where the increase takes place as in Figs. 5, 7, and 10, the arrangement described by Clark is produced; but where it is like that shown by Figs. 6 and 8, we get the form of interbrachial space said to be characteristic of *U. westfalicus*, and which may be extended to areas containing 7, 8, or even 9 plates.

Similar variations are found among the intersecundibrachs (interdistichals *auctt.*). Many specimens have two plates in a vertical row, as in *U. westfalicus*,

while others have only 1, or 3, 4, 5, 6, or 7 plates, variation from 2 to 4 or 5 occurring in the same individual. Here the increase is always by upward growth. I give a series of figures showing the manner of such increase, as well as the variations in form and arrangement in a number of specimens.



Variations in intersecundibrach spaces. 11 and 12 are from specimen No. 243; 13 from No. 57; 14 from No. 96; 15 from No. 29; 16 from No. 24; 17 and 19 from II *p*; 18 from No. 57 *b*; 20 from No. 20; 21 and 22 from No. 33 *a*; 23 from XIII *a*; 24 from VII *g*.

As already stated, these two kinds of plates belong to the category of supplementary plates, which serve to fill up spaces and increase the size of the visceral cavity. They were described by Wachsmuth and Springer in the Monograph of the Crinoidea Camerata, p. 110, where we stated, as a conclusion based upon the study of Palæozoic forms, that they "increase by multiplication in the growing animal, primarily in an upward direction, but partly by intercalation, — secondary plates being introduced between the primary ones." Accordingly, considerable irregularity is to be expected in their number and arrangement, and we should expect that this irregularity would be more pronounced in the older individuals; that there would be, in general, an increase in number corresponding to the growth of the individual, but not any absolute regularity in such increase. This agrees with the observed facts among many Palæozoic Crinoids, especially among the Flexibilia, and many Camerata. A fine illustration of it is seen in a species of "*Forbesiocrinus*" * from the lower Carboniferous, of which I have a large series of well-preserved specimens showing the stages of growth from very young to mature, which furnish the following data on this point:

* I have no doubt that the name "*Forbesiocrinus*" will have to be given up, as suggested by Bather. The English species taken by de Koninck as type is a *Taxocrinus* pure and simple, while the two specimens figured by him from Belgium surely belong to the type for which the genus *Onychocrinus* has been established. In 1888, after seeing Phillips's type specimen of *T. nobilis* in the Gilbertson collection, and also good specimens of *Sagenocrinus* from Dudley, I placed a label "*Sagenocrinus*" in our tray of *Forbesiocrinus Agassizi*, and I think it will be found that all the American species of *Forbesiocrinus* will fall readily under that genus, of which I have found a new species from our Upper Silurian also.

TABLE E.

Specimen.	Width of Calyx.	Brachials.		Number of Plates.	
		Length.	Width.	iBr areas.	iiBr areas.
1	8 mm.	.75	1.25	1– 1– 1	0–0–0
2	10 "	.75	1.75	1– 1– 1	0–0–0
3	10 "	.75	1.50	1– 1– 1– 2	0–0–0
4	10 "	.75	1.25	1– 1– 1– 1	0–0–0
5	10 "	.75	1.25	1– 1– 2	0–0–0
6	12 "	.90	2.00	3– 4	0–0–0
7	18 "	1.00	2.25	2– 3– 3– 4– 7	0–1–0
8	25 "	1.00	2.50	4– 3– 4– 4	1–1–0–1
9	25 "	1.12	2.75	5– 3– 4– 3– 4	1–1–0–1–0
10	30 "	1.00	3.00	5– 5– 4– 3	1–2–1–1
11	31 "	1.40	3.75	4– 3– 3– 3	1–1–1–1
12	35 "	1.50	4.25	6– 5– 5– 4	3–1–1–2
13	35 "	1.25	3.25	12–10– 8–11	5–4–3–4–4
14	37 "	1.30	4.00	8– 6– 7– 6	4–1–2–2
15	37 "	1.25	3.75	12–12–12–15	3–4–5–7–5
16	40 "	1.50	4.50	4– 6– 8– 6	4–1–2–2
17	40 "	1.30	4.00	15–16–12–13–23	4–5–4–4
18	44 "	1.30	4.25	14–14–14–17–15	8–6–5–4–5
19	50 "	1.30	4.50	15–12–16–15	4–6–6–7–5
20	55 "	1.50	4.50	15–10–17–16	4–6–6–7–6
21	55 "	1.75	4.50	15–16–12–16	5–6–4–3–5

Variations in size of brachials and number of interbrachials among twenty-one specimens of "*Forbesiocrinus*" of various sizes.

Although the conclusion above stated has been generally accepted by other authors, a demonstration of it by direct evidence has not heretofore been given. It is rare, in studying fossils, that an opportunity is presented for comparison of facts in a series of specimens of such extent and variety as is found in the collection of *Uintacrinus* before me in this investigation. With single specimens, or only a few of them, one cannot always be sure that the characters presented truly represent the species or genus as it is actually limited in nature. Indeed we may be totally misled in our estimate of its real character by something that is a mere individual peculiarity, *e. g.* Pl. VI., Fig. 5, on which, standing alone, we would say without question that the genus had an anal plate. This is especially true of Crinoids of the higher developed types, like the Camerata or Flexibilia, by reason of the complexity of their structure.

With a large series of specimens, however, the liability to error of this kind is much reduced, and by aggregating the facts thus presented it becomes possible to ascertain the rules that prevail in the structure and

development of a given type with a degree of confidence not otherwise attainable. This consideration will, I trust, be a sufficient warrant for my giving an exhibit of the observed facts in this case to an extent that might otherwise appear superfluous. For the purpose, therefore, of showing the extent of the variations in this genus, and of affording means of comparison as to characters already discussed, and also of demonstrating the soundness of the conclusion of Wachsmuth and Springer as to the mode of increase of the supplementary plates, I have collated upon the following table the facts as I have recorded them in about six hundred and fifty specimens; giving not only the number of interbrachials, but also the character of the base, and some other details. The table includes specimens from the several principal localities, and I have arranged them in the order of their size, beginning with the smallest:—

TABLE F.

Variations in Interbrachials and Base.

Specimen.			Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
				iBr.	iIIBr.		
Loc. 2.		LV *cc*	6.25	5– 7–	—	D	
	K*	1	6.25	4–	1–2–	D	
		LV *i*	7.50	4–	—	M	
		" *k*	7.50	4–	—	D	
		" *o*	7.50	5–	—	D	
		" *s*	7.50	4–	—	—	
		" *aa*	7.50	5–	—	D	
	K	26	7.50	5– 5–	2–	D	
	"	30	7.50	5– 5–	—	—	
	"	67	7.50	5– 5–	—	—	
		LV *ff*	9.00	4– 5–	—	M	
		132	10.00	5– 6–	—	—	
		LV *h*	10.00	5– 5–	—	D	
		" *bb*	10.00	7–	—	—	
	K	1	10.00	5– 6–	2–	D	
		146	11.00	5–	—	D	
		LV *t*	11.00	7–	—	—	
		37	11.00	8–	2–	D	
		216 *b*	12.00	4– 5–	2–	M	
		136	12.50	5– 6–	—	—	
		LV *l*	12.50	8– 8–	2–	D	
		" *z*	12.50	6–	—	M	4 basals.
		" *gg*	12.50	5–	—	D	
	K	24	12.50	5– 5–	—	D	
	"	68	12.50	5– 5–	—	D	
		LVIII *c*	14.00	5– 5– 6–	2–	D	
	K	23	14.00	5– 5– 6–	—	D	

* Specimens noted "K" belong to the Kansas University; the others to the writer.

Specimen.		Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
			iBr.	iIBr.		
K	36	14.00	8–	2–	D	
"	40	14.00	6– 9– 9–	—	—	
"	42	14.00	5– 6–	—	M	
	214	15.00	—	—	M	
	LV *ii*	15.00	6–	—	D	
	" *jj*	15.00	6– 6–	2–	—	
K	6	15.00	6– 6– 6–	—	D	
"	27	15.00	5– 5–	—	D	
"	49	15.00	5– 5–	—	D	
"	55	15.00	5– 5–	2–	D	
"	62	15.00	5– 5– 6–	—	D	
"	69	15.00	6– 8–	—	—	
	122	16.00	5–	—	—	
	124	16.00	7– 8–	2–	D	
	137	16.00	5– 6–	—	—	
	LV *d*	16.00	5– 5– 5– 6–	—	D	
	" *e*	16.00	5– 5– 6– 6–	—	D	
	" *dd*	16.00	6– 7–	3–	—	
	" *ee*	16.00	6– 5–10–	1–	D	
	" *hh*	16.00	7– 8–	—	—	
	" *oo*	16.00	6– 6–	—	D	
	" *pp*	16.00	5– 7– 7– 8–	—	—	
	LVIII *b*	16.00	3– 4–	2–	D	
K	51	16.00	5– 6–	2–	M	
"	53	16.00	5– 6–	—	D	
"	61	16.00	7– 9–10–	—	M	
Loc. 1.	XX *b*	16.00	13–15–	2–	—	
Loc. 2.	LV *r*	17.50	5–11–	—	D	
	" *v*	17.50	5– 7–	2–3–	D	
K	7	17.50	5– 6–	3–	D	
"	44	17.50	5– 7–	3–	D	
"	75	17.50	6– 6–	2– 3–	M	
	128 *a*	18.50	6– 6– 6–	2– 2–	D	
	LV *a*	18.50	5– 6–	—	D	
	" *b*	18.50	5– 7– 7–	2–	M	
	" *f*	18.50	5– 5– 5–	—	D	
	" *g*	18.50	5– 6– 6–	1– 2–	D	
	" *m*	18.50	5– 5– 5–	2–	M	
	" *x*	18.50	8–	2–	D	
	LVIII *e*	18.50	8– 9–	2– 3–	M	
K	4	18.50	6– 6– 6–	3– 3–	M	
"	12	18.50	7– 7–12–	—	M	
	14	18.50	6– 7– 7–	—	D	
"	18	18.50	6– 7–	—	M	
"	22	18.50	5– 6– 7–	2–	D	
"	50	18.50	6–	—	D	
"	58	18.50	6– 6– 6–	3–	—	
"	60	18.50	7– 7–	3–	M	
"	64	18.50	6– 7–	—	D	
"	72	18.50	7– 7–	2–	D	
Loc. 1.	XXVI *c*	18.00	5– 6–	3–	—	
	XVIII *a*	19.00	8–10–	5–	D	iBr touches basal.
Loc. 2.	129	19.50	6– 6–	2–	—	
	LV *n*	20.00	5– 5–	3– 4–	D	
	" *y*	20.00	6–	—	D	
	" *ll*	20.00	6– 6– 7–	1– 2–	—	

Specimen.		Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
			iBr.	iIBr.		
K	1	20.00	6- 6-	3-	D	
"	28	20.00	7- 7- 8-	2- 3-	D	
"	33	20.00	9-10-	—	D	
"	35	20.00	8-10-	2-	—	
"	48	20.00	6- 6-	2-	D	
"	54	20.00	5- 6-	—	D	
"	57	20.00	5- 7-	—	D	
"	63	20.00	6- 7- 8-	—	D	
	128 *b*	20.00	5- 7-	4- 4-	—	
	216 *a*	21.00	5- 5-	1-	D	
	LV *q*	21.00	5- 5-	1- 4-	—	
	LVIII *d*	21.00	10-	4- 4-	—	
	" *i*	21.00	5- 6- 7- 7-	—	—	
K	13	21.00	7- 8-10-	2-	D	
"	19	21.00	7- 9- 9-	—	M	
"	41	21.00	5- 5- 7-	2-	D	
"	46	21.00	5- 7- 8-	—	D	
"	52	21.00	5- 6- 6-	2-	M	
"	65	21.00	6- 6- 7-8-	—	D	
"	66	21.00	5- 5- 7-	—	—	
Loc. 1.	XX *a*	22.00	12-14-	3-	D	
Loc. 2.	213 *a*	22.00	5-	2-	D	
	216 *c*	22.00	5- 7-	2-	D	
K	39	23.00	9- 9-	3-	—	
"	45	23.00	5- 6- 7- 9-	—	—	
"	74	23.00	7- 8-	3-	M	
	LV *p*	24.00	6- 6- 8-	—	M	
	" *u*	24.00	6- 6-	3- 4-	—	
	123	25.00	6- 6- 6-	3-	D	
	130 *a*	25.00	6- 6-	—	—	
	" *b*	25.00	6- 6- 6-	—	—	
	212	25.00	5- 5- 7- 6-	2-	D	
	215	25.00	5- 6- 6- 9-	2- 2-	D	
	216 *e*	25.00	6-	3-	—	
K	29	25.00	6- 7- 7-	—	D	
"	47	25.00	7- 8-	5- 5-	M	
Loc. 1.	IX *b*	25.00	8-10-	—	D	
	78 *a*	25.00	7- 9-	2- 2-	M	
	104 *a*	25.00	9-10-	2-	D	
Loc. 2, K	10	26.00	5- 7- 7-	3-	M	
Loc. 1.	I *kk*	27.00	10-15-	3- 5-	M	
	VIII *b*	27.00	6- 8-	2- 3-	D	
	IX *d*	27.00	7- 8- 9-	2- 3-	D	
	XXII *d*	27.00	7- 7- 8-	—	D	
Loc. 2, K	3	27.00	5- 6- 6- 6- 7	—	D	
"	17	29.00	8- 9-	3-	D	
"	25	29.00	5- 6-	3-	—	
	LVIII *h*	29.00	5-	4-	D	
	216 *d*	30.00	6- 6-	2-	M	
Loc. 1.	XXXVI *b*	30.00	6- 9-	2-	D	
	XII *t*	30.00	10-11-	5-	M	
	" *u*	30.00	—	—	M	centrale elongate.
	XIX *a*	30.00	6- 7-	3-	—	
	XLV *l*	30.00	7- 8- 9-	2- 2-	M	
	II *m*	31.00	7- 8-	4-	D	
	VIII *s*	31.00	6- 7-	2-4-	—	

Specimen.		Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
			iBr.	iIBr.		
	54	31.00	9–10–	2–	D	
Loc. 2.	LVIII *a*	31.00	7– 8–9–10–16	—	D	
	" *f*	31.00	6– 7–	2	—	
	" *g*	31.00	6– 6–	4–4	—	
K	11	31.00	6– 7–	3–	D	
"	16	31.00	7–10–11–	—	D	
"	34	31.00	8– 9–	3–	D	
"	38	31.00	5– 5– 6–	—	D	
"	43	31.00	8–10–	—	M	
"	56	31.00	6–	—	—	
"	59	31.00	8–	5–5–	M	
Loc. 3.	180	31.00	6–	3–3–	—	
Loc. 1.	XLI *e*	31.00	6– 9– 8– 6–	3–2–	D	
	246	32.00	6– 8–	4–	D	
	II *h*	32.00	7–	4–4–	—	
	LXIV *h*	32.00	7– 7–	2–2–	M	
	VIII *t*	33.00	8– 8–	2–2–	—	
	XLI *g*	33.00	6– 6– 8–	1–	M	
	XLIX *b*	33.00	7– 7–10–	—	M	
	57	33.00	7–11–11–14–	—	M	4 basals.
Loc. 2, K	15	33.00	8– 9–	7–	D	
Loc. 1.	XIX *b*	34.00	9–	2–	—	
Loc. 2, K	9	35.00	8– 9–	5–7–	M	
"	21	35.00	5– 8–	3–	D	
Loc. 3.	177	35.00	7–11–	—	M	
Loc. 1.	90	35.00	6– 6– 7–	1–2–	D	
	104 *b*	35.00	10–16–	4–7–	D	ip.*
	107 *b*	35.00	9– 9–10–	—	D	
	III *g*	35.00	5– 6– 6–	2–	M	
Loc. 2, K	20	36.00	7– 8– 9–	3–5–	D	
Loc. 1.	218	36.00	9–10–	2–4–	M	
	XXI *b*	36.00	9–10–10–	—	D	
	XXIX *c*	36.00	12–12–	2–	M	
	XXXVI *a*	36.00	6– 7–	2–	D	
Loc. 2, K	32	37.00	6– 9–	5–4–	D	
Loc. 6.	211	37.00	9– 9–	4–	D	
Loc. 1.	LXIV *i*	37.00	6– 9– 7–	—	M	
	XLIX *f*	37.00	9–	4–	D	
	XII *m*	37.00	8– 9–	2–	M	
	II *f*	37.00	8–	2–4–	—	
	" *j*	37.00	7– 8–	2–4–	M	
	" *k*	37.00	6–10–	5–	—	
	" *n*	38.00	9–10–	4–	M	
	I *ee*	38.00	9–10–	3–3–	—	
	" *k*	38.00	8–	3–3–	M	
	" *y*	38.00	8– 9–	2–	M	
	VII *a*	38.00	9– 9–	3–	M	
	VIII *i*	38.00	7– 7– 8–	2–	D	
	XII *k*	38.00	9–12–	2–	D	
	XXIV *b*	38.00	11– 8+–	2–	M	
	XXIX *v*	38.00	8–	2–4–	M	
	" *gg*	38.00	11–12–	2–3–	M	
	L *f*	38.00	7–	—	D	
	LVI *f*	38.00	6– 6– 7–	3–3–	M	

* Specimens noted "ip." have interpinnulars visible.

Specimen.	Width of Calyx.	Number of Plates. iBr.	Number of Plates. iIIBr.	Form of Base.	Remarks.
LIX *a*	38.00	8– 8– 8^+–	—	D	
III *c*	38.00	7–13–	3–	—	
68	38.00	7– 8–	3–	D	
87	38.00	6– 7–	2–	M	
116 *f*	38.00	7– 8–	1–	D	
236	38.00	6– 7– 7– 6– 8	2–	M	
I *e*	39.00	9–	3–	M	
X *b*	39.00	7–	3–3–	D	
XIV *c*	39.00	6– 7– 8– 7^+–7^+–	2–	M	
XXXIV *f*	39.00	9–10–	2–2–	M	
XLV *aa*	39.00	7– 8– 9–	3–3–	M	
LXVI *d*	39.00	9–	3–3–	M	
3	39.00	6– 6–	2–3–	—	
58	39.00	8– 9–	2–2–	M	
I *b*	40.00	9– 9–	3–	D	
" *u*	40.00	7– 7–	2–	M	
II *g*	40.00	7– 7–	—	M	
VI *b*	40.00	6– 8–10–12–	2–	D	
XV *e*	40.00	6– 8–11–	2–	D	
XXII *c*	40.00	8–10–	3–	D	
XXXI *b*	40.00	7– 9–10–	—	D	
XLV *k*	40.00	6– 8– 8–	2–4–	M	
LVI *e*	40.00	9–12–	3–	M	
9	40.00	6– 7–	2–2–	M	
Loc. 6. 207	40.00	10–11–	4–	M	
Loc. 1. 230 *a*	40.00	7– 8–	2–	D	
247	41.00	3– 5–	2–3–	D	
XII *n*	41.00	11–16–	4–	D	
XXI *a*	41.00	6– 8– 9–	—	D	
XXV *b*	41.00	7– 7–	3–4–	D	
XXXIV *e*	41.00	6– 6– 7–	2–3–	M	
49 *b*	41.00	8–12–	3–	D	
I *h*	42.00	10–12–	4–	D	
XII *l*	42.00	6– 7– 7–	2–	D	
XLV *c*	42.00	10–14–12–	3–	M	ip.
XLVIII *g*	42.00	6– 7–	4–	D	
" *l*	42.00	8–	2–	D	
8 *b*	42.00	8–12–	3–	M	
85	42.00	11–12–	2–2–	D	
249 *e*	42.00	9–12–	1–	D	
I *rv*	42.00	8– 8– 8– 8–	4–	D	
II *r*	42.00	7–10–10–	3–3–	M	
1 *s*	44.00	6– 7–	2–2	—	
" *t*	44.00	6– 9–	2–	D	
" *cc*	44.00	8–10–	2–3–	M	
VI *d*	44.00	7–	3–4–	—	
VIII *e*	44.00	8– 8– 9–10–13–	—	M	
XII *e*	44.00	6– 7– 7–	2–	D	
" *w*	44.00	8– 9–	3–	M	
XII *ee*	44.00	8– 8–	3–	M	
" *gg*	44.00	9– 9–	3–3–	M	
XIII *h*	44.00	9– 10–	4–4–	M	double centrale.
" *m*	44.00	7– 7– 9–	1–2–	M	
XVII *b*	44.00	9–10–	2–2–	D	
XXVI *b*	44.00	9–11–	3–	D	
XXIX *m*	44.00	8–	2–	D	

Specimen.	Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
		iBr.	iIIBr.		
XXXIII *a*	44.00	8–11–	2–2–	M	
" *c*	44.00	9–11–10–13–	4	M	
XXXIV *c*	44.00	7– 8– 7–	3–4–	D	ip.
XLII *a*	44.00	12–12–	6–	M	ip.
XLIV *b*	44.00	6–	2–2–	—	
LVI *d*	44.00	6–	—	M	
LIX *b*	44.00	7– 7–	2–	M	
" *c*	44.00	7– 7–	1–2–	—	
20	44.00	7– 8– 8– 7–10	4–	M	
36	44.00	9– 9–11–11–10	—	D	
37	44.00	6–10– 7– 9– 9	—	D	
50	44.00	7– 7–	4–	D	
84	44.00	9–12–	2–2–	D	
89 *c*	44.00	6– 7–	3–	D	
116 *l*	44.00	6–10–	3–	M	
242	44.00	5– 5–	1–2–	M	
I *l*	45.00	11–12–	2–2–	—	
" *g*	45.00	7– 8– 8–	1–2–	M	
" *bb*	45.00	8– 8–16–	3–	D	
" *gg*	45.00	8– 9–	3–4–	M	
" *mm*	45.00	8–10–	2–5–	D	
" *ss*	45.00	8–10–	2–3–	M	
" *ww*	45.00	13–15–	2–2–	—	
IX *e*	45.00	8–	3–4–	—	
XII *q*	45.00	8– 8–10–	2–	M	
XXVII *a*	45.00	8– 9–	3–	M	centrale elongate.
XXIX *q*	45.00	9– 9–	2–	D	
" *s*	45.00	10–	3–	D	
XXXI *a*	45.00	7– 7– 9–	2–3–	M	
XXXVII *a*	45.00	9–15–	4–	M	
d	45.00	6–11–	—	D	
XLVIII *n*	45.00	5– 7–	2–	—	
LX *c*	45.00	9– 7–	3–4–	D	
LXI *f*	45.00	9– 8–	2–	D	
LXVI *c*	45.00	6– 6– 7–	5–4–	D	
14	45.00	8– 8–	3–3–	M	
116 *p*	45.00	8–10–	4–	D	
Loc. 3. 189	45.00	18–20–	4–	—	
Loc. 1. I *m*	46.00	7– 8–	3–3–	M	
VII *b*	46.00	7–10–	4–	—	
LIX *d*	46.00	15–	2–4–	—	
LXIV *g*	46.00	9– 8–	2–2–	M	
III *e*	47.00	10–15–11–	3–4–	D	
VIII *m*	47.00	10–11–11–	4–	M	
XIII *i*	47.00	10–10–	3–3–	D	
XIV *b*	47.00	14–15–	6–	D	
L *g*	47.00	5– 7–	2–	—	
LVII *a*	47.00	10–10–11–	2–	M	
LXIII *b*	47.00	10–11–11–	3–2–	M	ip.; double centrale.
LXIV *c*	47.00	6–	—	M	ip.
33 *b*	47.00	10–10–	4–	—	ip.
92 *a*	47.00	7– 9–12– 9– 9	2–	M	
116 *m*	47.00	7– 8–	4–	M	
227 *a*	47.00	6– 6–	2–2–	M	
60 *a*	47.00	8– 9–	2–	D	
230 *b*	47.00	11–10+–	2–	M	

Specimen.	Width of Calyx.	Number of Plates. iBr.	Number of Plates. iiBr.	Form of Base.	Remarks.
VII *c*	48.00	10–10–11–	5–6–	M	
XV *d*	48.00	8– 9–	5–	M	
XXVII *c*	48.00	10–12–	1–2–	—	
XLIV *a*	48.00	6– 8– 9–	2–3–	M	ip.
36 *b*	48.00	5–10– 8–	1–3–	D	
250 *b*	49.00	10 –9–	2–4–	D	
I *e*	50.00	13–13–	2–3–	—	
" *n*	50.00	6– 8–	3–4–	D	
" *o*	50.00	7– 9–	2–3–	M	
II *b*	50.00	5– 5–	2–	D	
" *d*	50.00	8– 9–	2–3–	M	
" *g*	50.00	9–10–	3–	D	
" *o*	50.00	8–12–	3–	M	
" *s*	50.00	8–10–	2–	M	
III *a*	50.00	8–	3–	M	
" *r*	50.00	9–11–	3–3–	—	
" *u*	50.00	8–	2–	M	
IV *e*	50.00	9–10–	3–	—	
V *b*	50.00	7– 8–11–	—	M	
VII *d*	50.00	7– 9– 9–	3–4–	D	
VIII *f*	50.00	9– 9–11–	2–2–	M	centrale elongate.
X *c*	50.00	9–	3–	M	double centrale.
XII *j*	50.00	9–10–	—	M	
" *r*	50.00	9–10–10–	3–3–	M	
XIII *a*	50.00	8– 8–	2–2–	D	3 IBB.
" *c*	50.00	8–11–13–	3–	M	ip.
" *g*	50.00	8– 8– 8–	2–	D	
XV *b*	50.00	—	—	D	
XXVII *b*	50.00	9–	4–	—	
XXIX *d*	50.00	12–12–	3–	D	
" *i*	50.00	10–12–14–	2–4–	M	
" *o*	50.00	10–11–	—	D	
" *r*	50.00	9–10–	1–	D	
XXXIV *b*	50.00	5– 6– 9–	2–2–	M	
XLIII *a*	50.00	7– 9–	5–	M	
XLV *n*	50.00	11–12–13–	3–5–	M	
XLVI *b*	50.00	9–10–	3–	M	
L *e*	50.00	8– 8–	—	M	
LI *c*	50.00	6– 8–	3–	M	
" *d*	50.00	—	—	D	
LVII *b*	50.00	9–11–	3–	D	
LX *a*	50.00	8– 9–	1–	D	
LXV *d*	50.00	5– 4– 6–	2–3–	D	
29	50.00	6– 8– 9–	3–3–	M	
40	50.00	7– 9– 9– 9– 8	—	D	
74 *b*	50.00	10–	4–	M	
81	50.00	13–14–	4–	D	
82	50.00	12–15–	4–	M	
83	50.00	8– 9–	3–	M	
89	50.00	6– 6–	1–2–	M	
100	50.00	8–	2–3–	M	
104 *c*	50.00	6– 7– 6– 7– 9	3–4–	D	iBr protuberant.
105 *a*	50.00	5– 6– 7–	—	M	
107 *a*	50.00	12–14–	4–	—	iBr protuberant.
116 *g*	50.00	8–12–	4–	D	ip.
" *n*	50.00	8– 9–	1–	M	

Specimen.		Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
			iBr.	iIIBr.		
	116 *o*	50.00	5– 5–	2–	D	
	219	50.00	7– 7– 9–	2–	M	
	232	50.00	8– 8–11–	2–4–	D	IBB minute.
	248	50.00	10– 6– 9–	3–4–	D	2 IBB.
Loc. 3.	176	50.00	15–	5–	M	
Loc. 6.	210	50.00	7– 7–	4–	M	
Loc. 1.	VII *e*	51.00	13–14–	2–	M	
	" *i*	51.00	12–13–	4–6–	—	ip.; centrale elongate.
	XIII *b*	51.00	11–11–	4–	D	
	XIV *d*	51.00	8– 9–	2–2–	D	
	XXIV *a*	51.00	9–11–	4–	M	
	XLV *a*	51.00	8–	3–	D	
	XLVIII *d*	51.00	12–10–11–	4–	D	
	III *d*	51.00	11–	2–	—	
	" *f*	51.00	9– 9–10–	—	—	
	22	51.00	7–10–11–	3–	M	
	25	51.00	10– 7–14–	4–4–	M	
	49 *a*	51.00	8–10–	2–	D	
	53	51.00	17–20–12–	5–	D	
	59	51.00	9–13–	2–	D	
	89 *b*	51.00	6– 7–	2–2–	M	
	195	51.00	7– 8–	3–	M	
	204	51.00	11–	2–2–	D	
	223	51.00	6–10–	1–2–	M	
Loc. 3.	195	51.00	7– 8–	3–	M	
Loc. 1.	I *a*	52.00	10–	2–	D	
	" *e*	52.00	9– 9–12–	3–4–	D	
	" *g*	52.00	12–14–	4–	—	
	" *r*	52.00	11–11–	3–	D	
	" *z*	52.00	9– 9–11–	5–5–	D	
	III *g*	52.00	7– 7– 9–	2–2–	M	
	" *j*	52.00	10–10–	3–	—	
	" *m*	52.00	5– 5–	—	M	
	" *u*	52.00	9– 9–	2–	—	
	V *a*	52.00	10–11–12–	4–6–	D	ip.
	VII *f*	52.00	8–	4–	D	
	VIII *g*	52.00	9–12–13–	2–	M	
	XII *f*	52.00	10–10–	4–	D	
	XIII *k*	52.00	9–10–	4–	M	double centrale.
	XXIX *a*	52.00	11–14–	6–6–	D	
	XLI *f*	52.00	10– 6– 7–	3–4–	D	
	XLV *e*	52.00	10–10– 8–	2–	M	double centrale.
	XLVIII *j*	52.00	12– 9–	3–4–	M	
	L *c*	52.00	5– 6–	2–	—	
	LVI *b*	52.00	11–	—	D	
	LX *f*	52.00	9–10–	2–2–	M	
	" *b*	52.00	8– 9–	4–	M	
	LXI *a*	52.00	9– 8– 8– 7–	2–	M	
	" *g*	52.00	12–10–11–	2–2–	M	
	LXIV *b*	52.00	9– 8–	5–	M	
	21	52.00	6–12–	2–	M	
	28	52.00	13–14–	4–4–	M	
	44	52.00	9– 8–10–	4–	D	ip.; IBB minute.
	48 *a*	52.00	8–10–	2–	D	
	51	52.00	—	—	D	
	52 *a*	52.00	9–12–12– 8–22	4–5–	M	2 IBB.

Specimen.	Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
		iBr.	iIBr.		
217 *b*	52.00	14–15–	4–	D	
249 *c*	52.00	9– 8–	5–	M	
251 *b*	52.00	8– 7– 7–	2–2–	D	
II *e*	53.00	7–11– 9–	3–3–	D	
I *ll*	54.00	9–	2–3–	D	
VII *h*	54.00	9–10–	3–	—	
XII *i*	54.00	9– 9–	4–	D	
" *h*	54.00	7–	—	D	
" *s*	54.00	9–12–10–	4–	M	
103	54.00	7– 8–	3–3–	D	
116 *g*	54.00	6–10–	4–	D	
248 *a*	54.00	7– 7– 7– 9–	2–2–	D	
I *p*	55.00	6– 7– 9–	2–3–	—	
" *tt*	55.00	7–10– 7– 8– 8	3–4–	D	
III *n*	55.00	9–11–	—	D	
VIII *k*	55.00	10–10–12–	2–4–	M	
XI *c*	55.00	8– 9–	2–	D	
XII *cc*	55.00	8– 9–10–	4–4–	D	
XXIV *d*	55.00	9–	2–2–	M	centrale elongate.
XXIX *k*	55.00	11–13–	3–3–	D	
XXXIII *e*	55.00	13–14–	3–	—	
XXXIV *i*	55.00	7–	2–	M	
XLI *b*	55.00	12–12–13–	4–4–	M	ip.
XLV *e*	55.00	9–10–	3–	M	
LI *e*	55.00	12–13–	4–	D	
LIV *b*	55.00	10–	2–2–	—	
LVI *c*	55.00	12–12–	2–4–	M	iBr protuberant.
LXV *a*	55.00	9–11–	4–	D	
8 *a*	55.00	11–12–	5–	M	
80	55.00	9–10–	5–	D	
II *a*	56.00	12–	4–5–	—	
IV *a*	56.00	12–	4–	—	
" *b*	56.00	12–15–	4–5–	M	
VIII *c*	56.00	9– 9–10–9	2–4–	D	
" *g*	56.00	10–11–	3–4–	D	
" *o*	56.00	10–11–	4–	—	iBr protuberant.
" *r*	56.00	10–13–	3–5–	D	
X *d*	56.00	10–	2–	—	
XI *d*	56.00	7– 9–11–	4–5–	M	
XII *d*	56.00	7– 8–10–	3–2–	D	
" *p*	56.00	11–12–	3–	M	centrale elongate.
" *x*	56.00	4– 9–	2–	M	
" *aa*	56.00	8– 9–10–	2–2–	M	
" *hh*	56.00	9–12–	2–3–	M	centrale elongate.
XIV *e*	56.00	8–	2–2–	M	
XV *a*	56.00	9– 7– 7–	2–	—	
XXIX *e*	56.00	14–16–13–14–	2–3–	M	
" *t*	56.00	6–	—	D	
XXXV *d*	56.00	9–10–	4–	D	
XLVIII *l*	56.00	7– 9– 8–	2–	M	
" *m*	56.00	11– 9– 9–	2–	M	
XLIV *c*	56.00	—	—	D	
L *a*	56.00	11– 7+–11–	4–4–	M	
" *b*	56.00	11–12–12–	4–	—	
LIV *g*	56.00	5– 6– 9–	2–2–	D	
" *o*	56.00	11–11–	5–	—	ip.

Specimen.		Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
			iBr.	iiBr.		
	LX *b*	56.00	10–10–	3–	D	
	" *d*	56.00	8– 5–	3–4–	M	
	1	56.00	11–11– 9+–	4–0–	—	iIIBr wanting in one ray.
	11	56.00	8– 9– 8–	—	M	
	12	56.00	9–10–	2–	M	
	17	56.00	10–10–	5–5–3–3–5	M	
	31	56.00	10–10–	—	M	
	35 *c*	56.00	7– 7– 8–	3–4–	M	
	48 *b*	56.00	17–20–13+–	5–	D	ip.
	61	56.00	10–22–12–13–	—	M	3 iBr touch basals.
	62	56.00	10–11–12–	3–	M	ip.
	70	56.00	8– 9–	—	D	
	86	56.00	9–10– 7+–	5–	D	
	88	56.00	8– 7– 8– 9– 9	—	D	
	106 *a*	56.00	10–	4–	D	
	116 *i*	56.00	6– 7–	2–	M	
	224	56.00	7– 8–	2–3–	M	
	235	56.00	7–11– 8–	4–	M	
	240	56.00	8– 9–10–11–	2–3–	D	IBB minute.
	241 *c*	56.00	4– 7–	—	D	
	244 *b*	56.00	9–10–12	3–	—	
	251 *a*	56.00	13– 8–	4–	M	ip.
Loc. 3.	173	56.00	12–15–	5	—	iBr protuberant.
Loc. 1.	I *d*	57.00	6–11–	4–	—	
	" *j*	57.00	11–12–	—	M	
	" *aa*	57.00	8–11–	4–	M	
	" *uu*	57.00	13–15	5	—	
	II *t*	57.00	7–	4–4–	—	
	IV *f*	57.00	12–12–	8–	M	
	VIII *d*	57.00	9–10–	2–2–	—	
	" *h*	57.00	8– 9– 9–	2–4–	M	
	" *l*	57.00	10–12–14–	3–3–	M	
	" *n*	57.00	10–12–	3–	—	
	XII *g*	57.00	5– 6–	2–2–	M	
	" *v*	57.00	11–12–	3–	D	
	" *y*	57.00	9–11–	3–4–	M	
	XXXVII *c*	57.00	9–	5–6–	—	
	L *d*	57.00	12–	6–	M	
	LII *b*	57.00	9–12–	5–	M	double centrale.
	LXIV *j*	57.00	11–11– 8–	4–2–	M	
	27	57.00	10–10–	4–	M	iBr touches basal.
	35 *a*	57.00	14– 9–11– 8+–	2–3–3–	M	
	' *b*	57.00	10–10–10–	5–	M	
	108	57.00	9– 9–	2–2–	D	
	117	58.00	13–11–	5–5	—	ip.
	217 *c*	58.00	11–	5–	—	
	XXIX *g*	59.00	12–14–	2–	D	
	XXXV *e*	59.00	10–13–	3–4–	M	
	52	59.00	14–	—	D	
	I *f*	60.00	7–12–	2–2–	M	
	" *dd*	60.00	11–12–	4–4–	—	
	" *ii*	60.00	7– 1– 1–	4–	M	
	II *l*	60.00	11–10+–	4–4–	D	
	" *p*	60.00	8– 9–	3–4	—	
	" *u*	60.00	7– 7– 8–	4–4–	—	
	III *b*	60.00	11–10+–	3–	M	

Specimen.		Width of Calyx.	Number of Plates. iBr.	iIBr.	Form of Base.	Remarks.
	" *h*	60.00	9–10–	4–	—	
	" *i*	60.00	9–10–	2–	M	
	" *o*	60.00	9– 8–	4–	—	
	" *t*	60.00	9–11–	4–4–	—	
	IV *d*	60.00	10–11–	4–	M	
	V *c*	60.00	15–	5–6–	—	
	VII *g*	60.00	10–15–	4–7–	M	centrale elongate.
	XII *b*	60.00	11–11–	4–	M	
	XIII *f*	60.00	9–11–	3–3–	M	
	XXIX *f*	60.00	9–11–	2–	M	
	XXXII *a*	60.00	7– 8–	2–2–	M	
	XXXIII *d*	60.00	13–14–	3–	D	
	XL *a*	60.00	9– 7– 7– 8–	2–	M	
	XLIV *f*	60.00	14–10–	5–3–	M	ip.
	XLV *p*	60.00	7–11– 8–	2–2–	M	
	XLIX *d*	60.00	14–10+–	—	D	
	LXI *c*	60.00	12–12–	6–5–5	M	ip.
	" *d*	60.00	10– 9– 9–	4–3–	M	
	15	60.00	10–11–	2–	M	
	35 *d*	60.00	14–	2–4–	—	iBr protuberant.
	42	60.00	7– 8– 5– 6– 8	3–3–	D	3 IBB.
	45 *a*	60.00	13– 9–11–10–14	—	D	
	79	60.00	10–13–10	2–4–	M	
	89 *a*	60.00	5– 6–	2–1	M	centrale elongate.
	116 *k*	60.00	8– 8–	2–	M	
	225	60.00	14– 8–	1–	M	iBr protuberant.
	226	60.00	14–12–11–	2–	M	
	233	60.00	11–12– 9–	4–4–	D	
	241 *a*	60.00	13–12–12–	5–5–	D	
	245	60.00	10–11–12–	3–4–	M	
	249 *b*	60.00	13– 9+–	—	D	ip.
Loc. 6.	209	60.00	12–	—	M	
Loc. 1.	1 *x*	61.00	9–10–12–12–	3–4–	M	
	" *hh*	61.00	18–12–14–14–14+	2–2–	D	
	IX *c*	61.00	8–	—	M	
	XXIX *l*	61.00	8– 9– 9–	3–	M	
	XLV *p*	61.00	12–13–	4–5–	—	
	XLVIII *b*	61.00	12– 8– 8–	4–3–	M	
	LI *b*	61.00	9–16–18–	4–	M	double centrale.
	I *w*	62.00	10–10–11–	4–	M	
	" *oo*	62.00	8– 9–	3–3–	M	
	III *p*	62.00	11–	4–5–	—	
	VI *c*	62.00	21–	7–8–	—	
	VIII *a*	62.00	7–10–	2–3–	—	
	XI *b*	62.00	7–10–10+–	2–2–	M	
	XII *c*	62.00	10–12–12–	2–3–	M	
	" *bb*	62.00	9– 6–10–	4–4–	M	
	" *ff*	62.00	12–12–15–	5–	M	
	XVII *a*	62.00	8– 8–	2–	—	
	" *c*	62.00	10–11–	2–4–	M	
	XXV *a*	62.00	12–12–	3–4–	—	ip.
	XXIX *b*	62.00	16–14–16–17–	3–3–	M	
	" *h*	62.00	10–14–	3–4–	D	
	" *n*	62.00	13–10–15–	3–4–	D	
	" *u*	62.00	9–10–	5–7–	M	
	XXXIII *b*	62.00	11–13–10–	3–4–	M	

Specimen.	Width of Calyx.	Number of Plates.		Form of Base.	Remarks.
		iBr.	iIIBr.		
XXXV *a*	62.00	10–10–14–	3–6–	D	
" *c*	62.00	11–12–	5–6–	M	
XLVI *a*	62.00	10–10–	—	M	
LX *e*	62.00	7– 8–	2–	M	
LXII *b*	62.00	11–12–	4–4–	M	ip.
LXVI *a*	62.00	8– 9– 9–10–	2–	M	iBr touches basal.
" *b*	62.00	11– 9–	4–	D	6 BB; iBr touches basal.
5	62.00	10–	4–5–	—	
13	62.00	7– 7– 8–	2–3–5–	M	
24	62.00	5– 6– 6⁺–	—	M	
26	62.00	6 8–	3–	D	
38	62.00	10–11–	3–	D	
41	62.00	16–15–14–19–	5–6–6–	D	ip.
46 *c*	62.00	8– 9–	2–	M	
47 *b*	62.00	7 9–	2–2–	D	
94	62.00	10–10–14–	3–6–	D	
116 *r*	62.00	19–	4–	—	
220	62.00	12–12–	4–	D	
228 *b*	62.00	9– 9– 8–	—	D	
249 *a*	62.00	10– 7–	3–	D	
Loc. 3. 186	62.00	8–	2–2–	—	iBr protuberant.
Loc. 1. I *ff*	64.00	1312–10–	5–5–	M	
XLV *h*	64.00	11–11–12–10–	3–4–	D	ip.
39	64.00	8– 9–10–11–	4–3–4–	D	ip.
234	64.00	13–14–	4–	—	
I *c*	65.00	10–	5–5–	—	
II *i*	65.00	13–10–	—	M	
VIII *j*	65.00	12–12–11–	3–	D	
XII *o*	65.00	6– 6– 7–	2–5–	M	
XXVI *a*	65.00	18–	6–7–	M	
XXXVII *b*	65.00	10–10⁺–	4–	M	
LII *c*	65.00	7– 8–	1–1–	—	
LIV *i*	65.00	9– 8– 7–12– 9	4–	M	ip; 6 BB.
" *m*	65.00	9–	2–	M	ip.
XLV *q*	65.00	10–10–13–	4–	D	
16	65.00	14–	3–	M	
33 *a*	65.00	17–15–16–	5–6–	M	ip.
34	65.00	9– 8–11–	3–5	M	ip.
46 *a*	65.00	12–12–	5–	D	3 IBB.
217 *a*	65.00	11–11–	3–3–	D	ip.
270	65.00	10–	—	M	6 BB.
III *k*	66.00	11–12–13–	6–6–	M	
XLV *f*	66.00	13–15–	4–	—	
6	66.00	7–10–	4–	M	
I *pp*	67.00	15–14–14⁺–	—	—	
" *gg*	67.00	14–13–13–12–11	—	M	
III *l*	67.00	11–	4–	—	
XI *a*	67.00	8–10–	2–2–	D	
XIX *c*	67.00	11–11–	5–5–	—	
XLI *a*	67.00	10– 8–	4–	D	
XLV *bb*	67.00	10– 8–	2–	D	
43	67.00	11– 5–	2–3–	D	ip.
243	68.00	11–12–	4–	M	
XII *dd*	69.00	8–10–	4–5–	M	ip.
XXII *a*	69.00	15– 9–10–	3–5–	D	
XXX *a*	69.00	15–16–	4–	—	

Specimen.	Width of Calyx.	Number of Plates. iBr.	iIIBr.	Form of Base.	Remarks.
XXXIV *a*	69.00	13–10–11–	3–4–	M	
XLI *c*	69.00	12–	5–	—	
LXIV *d*	69.00	13–11–11–	5–4–	D	
10	69.00	16–16–	4–	M	ip.
19	69.00	13– 9+–	—	M	
23	69.00	12–13–15–11–12–	—	M	
69 *a*	69.00	10– 9–12– 7– 7+–	2–2–3–	D	
222	69.00	12– 9+–	4–	D	
237	69.00	14–10–11–	4–4–	D	
250 *a*	69.00	9–12–	4–	M	ip.
251 *c*	69.00	10–11–11–11–	4–2–	D	ip; iBr protuberant.
II *c*	70.00	12–10–	2–	—	
LXIII *c*	70.00	12–14–12–	3–2–	D	ip.
60 *a*	70.00	9–11–	2–	M	
229	70.00	13–11–9+–	2–2–	M	iBr protuberant.
VI *a*	72.00	8– 7–	2–3–	D	4 IBB.
X *a*	72.00	10– 7–11	—	M	
XII *a*	72.00	10–11–14–	3–3–	M	
LXIV *h*	72.00	23–16–	5–4–	M	
LIV *a*	73.00	10– 9–10–	2–4–	D	
IX *a*	74.00	10– 7–10–	2–5–	D	ip.
XLV *l*	75.00	11– 8–	4–	D	
" *n*	75.00	10– 8–	5–2–	D	ip.
228 *a*	75.00	10–12–14–	—	M	

Inspection of the foregoing table shows that there is no normal number of interbrachials, and that no regularity can be found in the variations except such as are traceable to individual growth. The greatest regularity is in the smallest specimens, which have as a rule five or six plates to the area, and frequently the same number in all the areas exposed. As the size increases, the number of interbrachials increases in one or more interradii, but scarcely ever the same in all. From the nature of these plates we should expect to find just this kind of irregularity. For it is not probable that the plates of the calyx and their ligamentous or muscular connections would be of equal strength throughout, and hence the expansion of the visceral mass would cause the plates to open, or new stereom to be deposited, first at the points of least resistance. Therefore, while the number of interbrachials might be quite uniform in young individuals, we can readily see how one or more supplementary plates might be introduced in one interradius and not in another. Among the adult specimens numbers from eight to ten, in which there is generally a central plate surrounded by a band of others, are the most frequent; but 23 per cent of the specimens have their iBr spaces composed of seven plates or less, in which there

is no enclosed plate, and 51 per cent have more than nine plates in one or more areas.

By combining the foregoing data into a few classes according to the maturity of the specimens, we are enabled to obtain an average whereby the influence of the misleading irregularity in individual specimens is to a large extent eliminated. I have accordingly taken two types of interbrachial areas, viz.: one containing not more than seven plates in any area, which might be said to be the *U. westfalicus* type; and the other containing nine plates or more in some of the areas, which would represent the *U. socialis* type, according to Clark. These I have arranged in four groups of minimum, medium, large, and maximum sizes. This process gives the following interesting and significant result: —

RECAPITULATION AS TO INTERBRACHIALS AND BASE.

	Number of Plates in Interbrachial Areas.						Form of Base.		
Width of Calyx.	Per cent 7 or less.	Not over 7 in any.	Over 7 in some.	Not over 9 in any.	Over 9 in some.	Per cent over 9.	Monocyclic.	Dicyclic.	Per cent of Dicyclic.
Less than 25 mm.	**73**	81	30	100	11	**10**	20	62	**77**
25 to 49 "	**26**	52	147	122	77	**39**	84	84	**50**
50 to 60 "	**7**	18	228	80	166	**67**	121	87	**41**
61 to 75 "	**2**	2	102	16	88	**84**	50	35	**41**
Totals.	**23**	153	507	318	342	**51**	275	268	**49**

From this table we can see the general tendency of the individual variations and modifications by growth of the supplementary plates, to a degree of certainty which gives to the conclusion of Wachsmuth and Springer the force of a fixed law. In the smallest class 73 per cent of the specimens have but few interbrachials, and only 10 per cent have more than nine; while in the class of maximum size these proportions are reversed, 84 per cent of the specimens having more than nine. In the intermediate classes the gradual progress of these differences is well marked.

The development of the intersecundibrach spaces and interpinnulars is considerably more irregular, and yet it follows the same general rule. The smaller number prevails among the smaller specimens, and is the exception among the larger; while the proportion of the larger numbers increases

decidedly with the size of the specimens. The following averages, taken from the general table, show this very clearly: —

RECAPITULATION AS TO INTERSECUNDIBRACHS AND INTERPINNULARS.

Width of Calyx.	Number of Plates in IIIBr Areas.					Interpinnulars.	
	1 or 2.		3 or 4.	5 or more.			
	Per cent.	Number.	Number.	Number.	Per cent.	Number.	Per cent.
Less than 25 mm.	**62**	32	19	1	**2**	0	**0**
25 to 49 "	**32**	63	90	16	**9**	8	**4**
50 to 60 "	**28**	64	126	32	**14**	14	**6**
61 to 75 "	**15**	15	49	28	**30**	19	**20**

What, then, have we left to distinguish the European from the American species? Schlueter's specimen of *U. westfalicus*, and I judge also Bather's, from his account of its discovery, is more plump and rotund than *U. socialis* as hitherto found. This might be due to a greater thickness of the plates, but this is not probable. It would seem probable that the specimens of *U. westfalicus* thus far discovered were isolated, — in the sense that they were free from attachment to others, — and were preserved in their rotund form by some exceptionally favorable condition of fossilization, as the specimens of *Marsupites* are frequently found. Even the swelling of the interradii we have occasionally in the American specimens. If *U. westfalicus* is a good species, then it exists in America, along with *U. socialis*, and in the same colony; for, as already stated, and as clearly appears by the foregoing table, there are specimens which, in the essentials relied upon to separate the species, are not distinguishable from it. But these specimens, considering their mode of occurrence, and the great variation exhibited in the supposed distinctive characters, cannot be separated from *U. socialis*. From all these facts it follows irresistibly, in my opinion, that *U. westfalicus* cannot be distinguished from *U. socialis*, and that the two represent but one species, which of course must take the older name, *U. socialis*.

The fact that they come from different continents is of itself no proof that these are distinct species. There is no *a priori* reason why a species found in America should not occur in Europe also. It has been the custom

of Palæontologists — too frequently — to assume that fossils so occurring were distinct. I have long been of the opinion that this has been too much taken for granted, without facts to support the assumption. With regard to the Crinoids, there are certain Upper Silurian forms in which I do not believe it possible to separate the English and Swedish species from the American, by any characters preserved in the fossil state, and the same may perhaps be true of some Subcarboniferous forms.

The best evidence on this point, however, is furnished by the living Crinoids, of which there are a number of species, both stalked and unstalked, which have a geographical range fully as great as this would be, and some of them greater.

The following data as to the Geographical Distribution of Stalked Crinoids and Comatulæ in the present seas, taken from the works of P. Herbert Carpenter,* will afford instructive proof on this point: —

Rhizocrinus lofotensis: Both sides of the Atlantic; Lofoten Islands to Caribbean Sea, and South Atlantic, Lat. 35°, 39′ S.

Rhizocrinus Rawsoni: Both sides of the Atlantic; Azores to Caribbean Sea, Yucatan Bank, and off Panama.

Hyocrinus bethelianus: Mid Atlantic; Southern Ocean; East Pacific.

Antedon tenella: Both sides of the Atlantic; Coast of Portugal, Scandinavia, and New England.

Antedon carinata: Both sides of the Atlantic; St. Helena, Caribbean Sea, coast of Brazil. Red Sea; Indian Ocean; Zanzibar; Mauritius, Madagascar, and Ceylon; East Pacific; Chili.

Antedon quadrata, *A. Eschrichti*, *A. prolixa*, and *A. Dubeni:* All on both sides of the Atlantic.

Actinometra pulchella: Both sides of the Atlantic; off Rockfort, St. Paul's Rocks, Bay of Biscay, Caribbean Sea.

Actinometra parvicurva: Both sides of the Pacific; Borneo, Philippines, Japan, Fiji Islands, Peru, Cape of Good Hope; Ceylon.

In order to afford those interested an opportunity to see the material on which this paper is chiefly based, I have, in addition to the slab already mentioned, presented to the Museum of Comparative Zoölogy the principal type specimens figured on Plates II. to VII. inclusive. I have also placed

* "Challenger" Rep. on Stalked Crinoids, pp. 386–7; Comatulæ, pp. 200, 304, 373 *et seq.* Jour. Linn. Soc., Vol. XXIV., p. 68.

in the National Museum at Washington a large slab containing specimens exhibiting most of the characters herein discussed. I have also sent a series of these specimens to the British Museum, and to the Royal Museum of Natural History at Berlin, where they will be accessible to British and European investigators.

PLATE I.

Uintacrinus socialis Grin.

Specimens drawn from Slab No. VIII; reduced to about .25 natural size. To show the length of arms, and relative proportions of calyx, arms, and brachials in adult and young individuals.

VIII *a* has the longest arms yet found preserved, the longest being 40 inches, or 100 cm. It was evidently about 25 cm. longer, or about 125 cm. in all.

The small specimen, VIII *b*, has arms about 30 cm. long, with a probable additional length sufficient to make them 55 cm.

VIII *c* and *d* are large specimens overlying some of the arms of *a*.


b
Scale of Inches
1 2 3 4 5 6 7 8 9 10 11 12
d
c
a

PLATE II.

UINTACRINUS SOCIALIS. A SERIES SHOWING VARIATIONS IN THE BASE.

Fig. 1.	Monocyclic; regular; centrale of maximum size.	Specimen No. X *a*.
" 2.	Monocyclic; regular; centrale of nearly minimum size.	No. 60 *a*.
" 3.	Monocyclic; regular; centrale elongate.	No. 89.
" 4.	Monocyclic; irregular; double centrale.	No. X *c*.
" 5.	Dicyclic; irregular; double centrale and 1 IB.	No. 248.
" 6.	Dicyclic; irregular; 3 IBB. Angles of centrale radial next to basals, interradial next to infrabasals.	No. 46 *a*.
" 7.	Dicyclic; irregular; 4 IBB.	No. VI *a*.
" 8.	Dicyclic; irregular; 3 large and 2 small IBB.	No. XXXVI *a*.
" 9.	Dicyclic; irregular; IBB appearing as minute points.	No. 232.
" 10.	Dicyclic; regular; IBB fully developed.	No. 69.
" 11.	Dicyclic; regular; IBB very acuminate.	No. 39.
" 12.	Dicyclic; regular; IBB disturbed by pressure and partly pushed out of level of basals.	No. 47 *b*.
" 13.	Dicyclic; regular; IBB separated by pressure in fossilization.	No. 36 *b*.
" 14.	Monocyclic; irregular; quadrangular centrale and 4 basals. Loc. 2.	No. LV *z*.
" 15.	Monocyclic; irregular; hexagonal centrale and 6 basals.	No. LIV *l*.

(All figures enlarged × 3. Figs. 5 and 8 by Chapman; the others by Mrs. Ricker.)

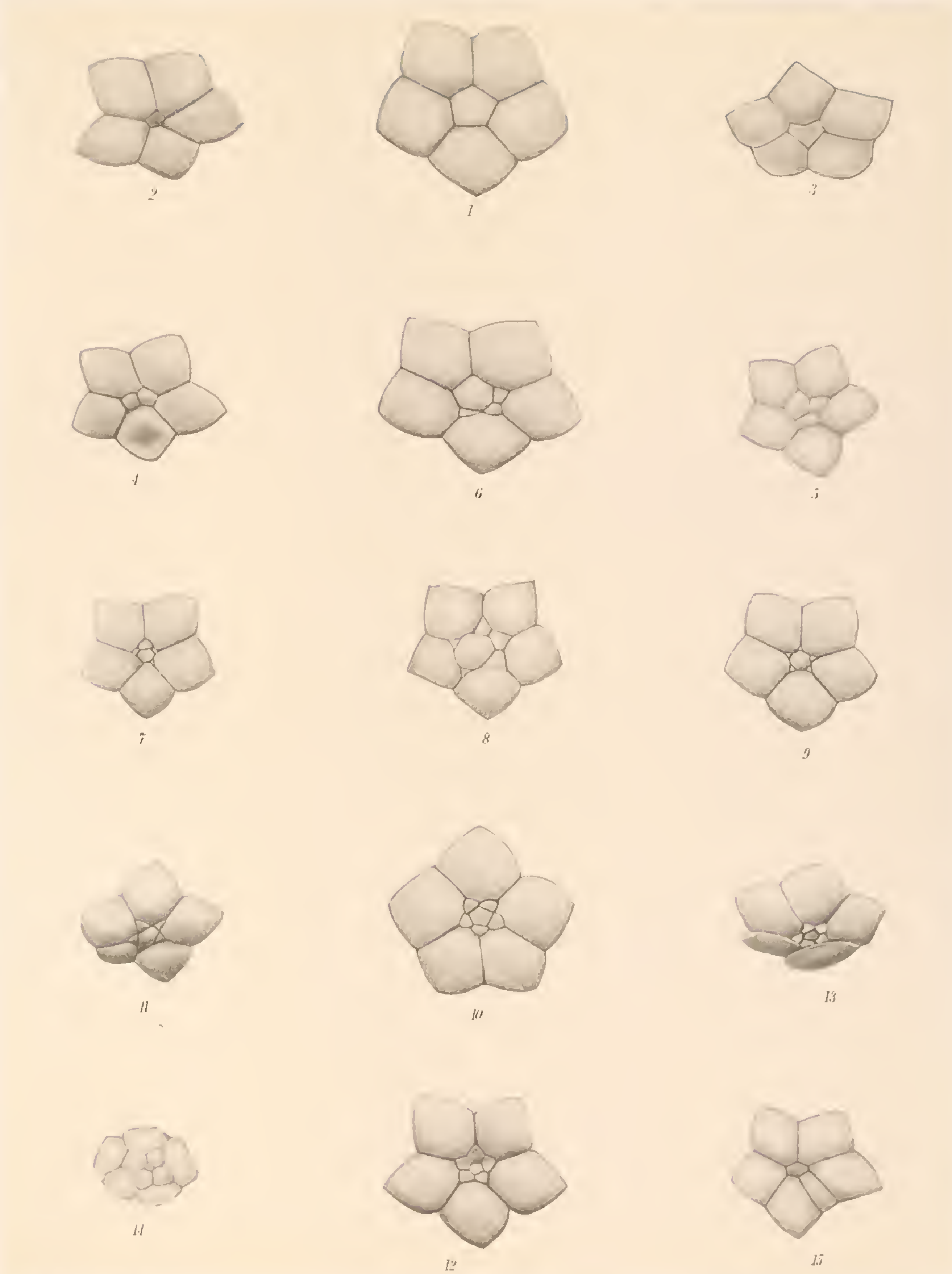

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PLATE III.

UINTACRINUS SOCIALIS. A SERIES SHOWING VARIATIONS IN FORM, SIZE, AND OTHER CHARACTERS.

Fig. 1. Specimen, with three individuals, showing dicyclic and monocyclic forms of base, and maximum and small size, lying together in close contact on the slab; the black membrane lining the calyx is also shown at the edge of the broken plates. Specimen No. IX *a*, *b*, *c*.

" 2. Dicyclic specimen of large size, with the interbrachial areas convex and protuberant; one ray is irregular in having 4 primibrachs. No. 45.

" 3. Small specimen from Loc. 2; monocyclic; with 3 and 5 plates in iBr areas. No. LV *m*.

" 4. Similar specimen; dicyclic; with 3 and 4 plates in iBr areas. No. LVIII *b*.

" 5. One of the smallest specimens; monocyclic; with 4 plates in iBr area, and either two or no fixed pinnules. No. LV *i*.

" 6. Specimen of medium size; monocyclic; with 5 plates in each iBr area visible. No. 242.

" 7. *Uintacrinus westfalicus* Schlueter. Figure of the type specimen for comparison. (After Schlueter.)

(All figures natural size. Figs. 1–5 by Chapman; Fig. 6 by Mrs. Ricker.)

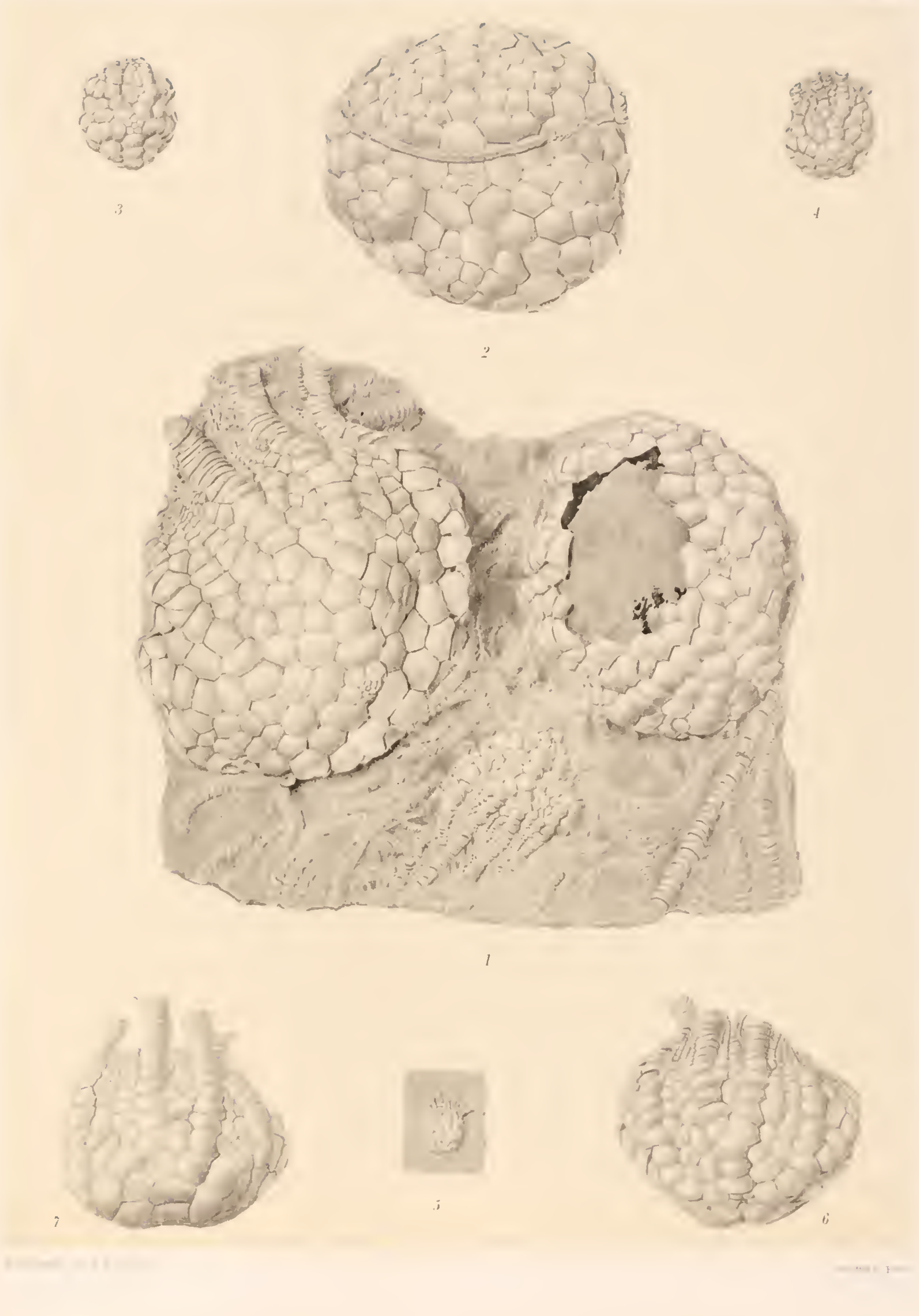
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PLATE IV.

UINTACRINUS SOCIALIS. STRUCTURE OF THE VENTRAL SIDE.

Fig. 1. Specimen vertically compressed; showing the black carbonaceous integument studded with irregular calcareous spicules not in contact; mouth and ambulacra in place, and the large anal tube lying flat upon the disk. Specimen No. 75.

(See Pl. VII., Fig. 1, *infra*, for enlarged photograph of disk.)

" 2. Similar view of another specimen; the disk paved with smaller spicules, the ambulacra in place, and the anal tube curled and crushed upon itself. No. 71.

" 3. Specimen diagonally compressed; showing part of disk, with ambulacra near the mouth, and the anal tube nearly erect between the arm bases. No. 76.

" 4. Specimen laterally compressed, with middle of disk pushed upward and surmounted by the anal tube in an erect position. No. 148.

" 5. Specimen laterally crushed; the disk and anal tube, instead of being pushed upward as in Fig. 4, have fallen inward, and have been caught between the two opposite walls of the calyx when the Crinoid was embedded; the anal tube is brought into view by the removal of some plates of the outer wall of the calyx. The black membrane lining the whole calyx is shown at the lower part of the fracture. No. 30.

(In the last two figures, for greater clearness in drawing, the artist was instructed to leave out of view a confused mass of calyx plates, brachials and pinnules forming the background of the tube. This does not impair the accuracy of the drawing of the structures desired to be shown, as the tube in each case is as plain and well defined in the specimens as here shown.)

" 6. *Actinometra strota* P. H. C. View of the disk, showing position of mouth and anus, and distribution of ambulacra. $\times$ 2. (After Carpenter.)

Figs. 7–9. *Actinometra paucicirra* Bell. $\times$ 3; and

Fig. 10. *Actinometra nobilis* P. H. C. $\times$ 3½. Showing variations in the base of this genus. (After Carpenter.)

(All figures not otherwise noted natural size. Figs. 1–5 by Chapman.)

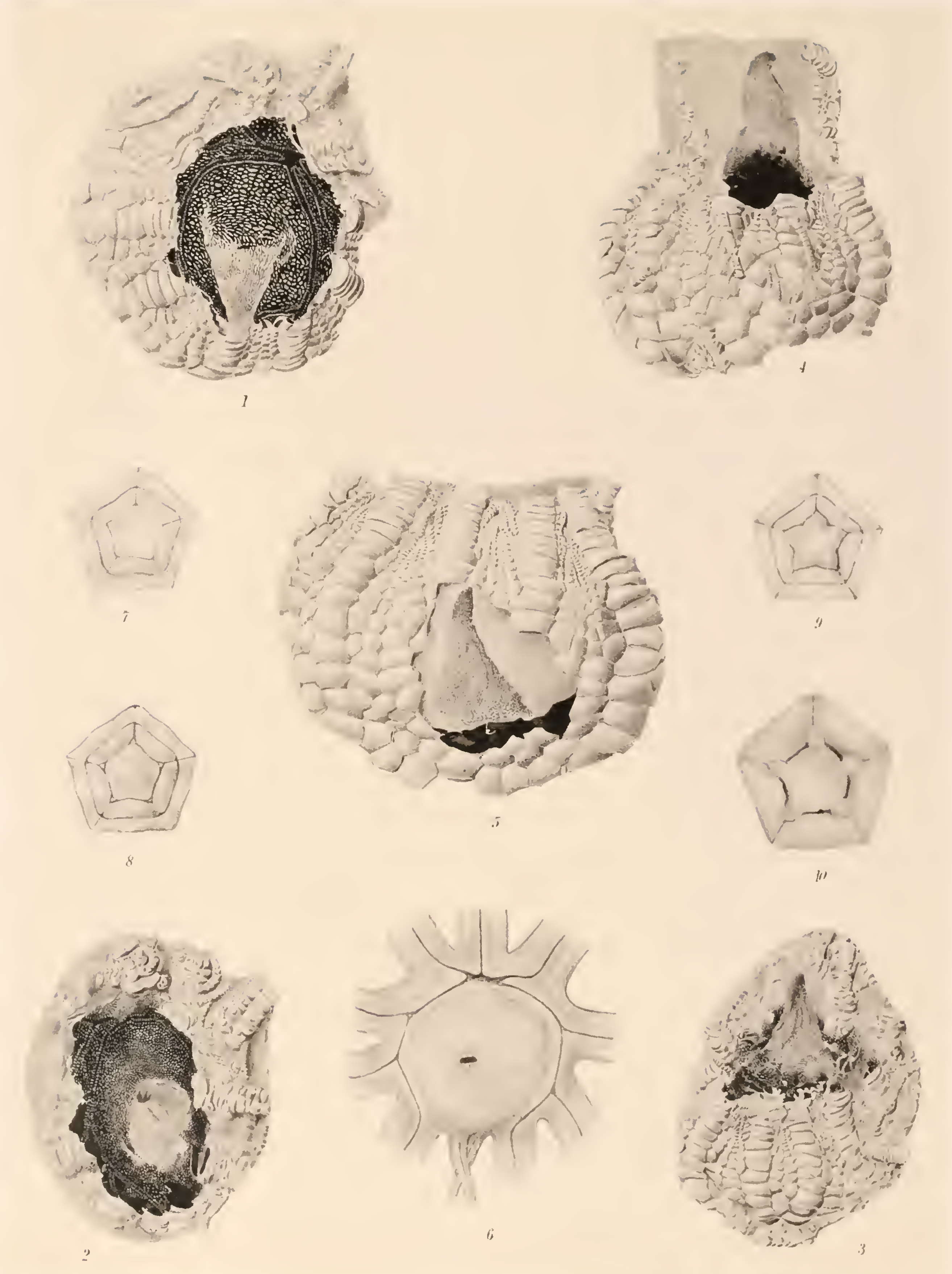

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PLATE V.

Uintacrinus socialis. Arms and Pinnules, and Interbrachial Areas.

Figs. 1 to 4. A series of specimens from maximum to small size, showing form and proportions of arms, pinnules, and brachials in individuals of various stages of growth. Specimens Nos. 117, 3, 78 *a*, and XX *a*.

Fig. 5. Medium specimen, dicyclic; with 3 and 5 plates in interbrachial areas. No. 247.

(See photograph of base of this specimen enlarged, Pl. VII., Fig. 3, *infra*.)

" 6. Large monocyclic specimen; showing variation of 7 to 14 plates in iBr areas. No. 25.

" 7. Maximum specimen, dicyclic; showing profuse development of iBr and iIIBr plates. No. 41.

" 8. Specimen laterally compressed; showing the fixed and proximal free pinnules, and the anal tube in natural position. No. 150.

" 9. Pinnule from upper part of arm; showing dice-box shape of pinnules. × 5.

(All figures not otherwise noted natural size. Figs. 1, 2, 3, 4, 6, 7, 8 by Chapman; 5 and 9 by Mrs. Ricker.)

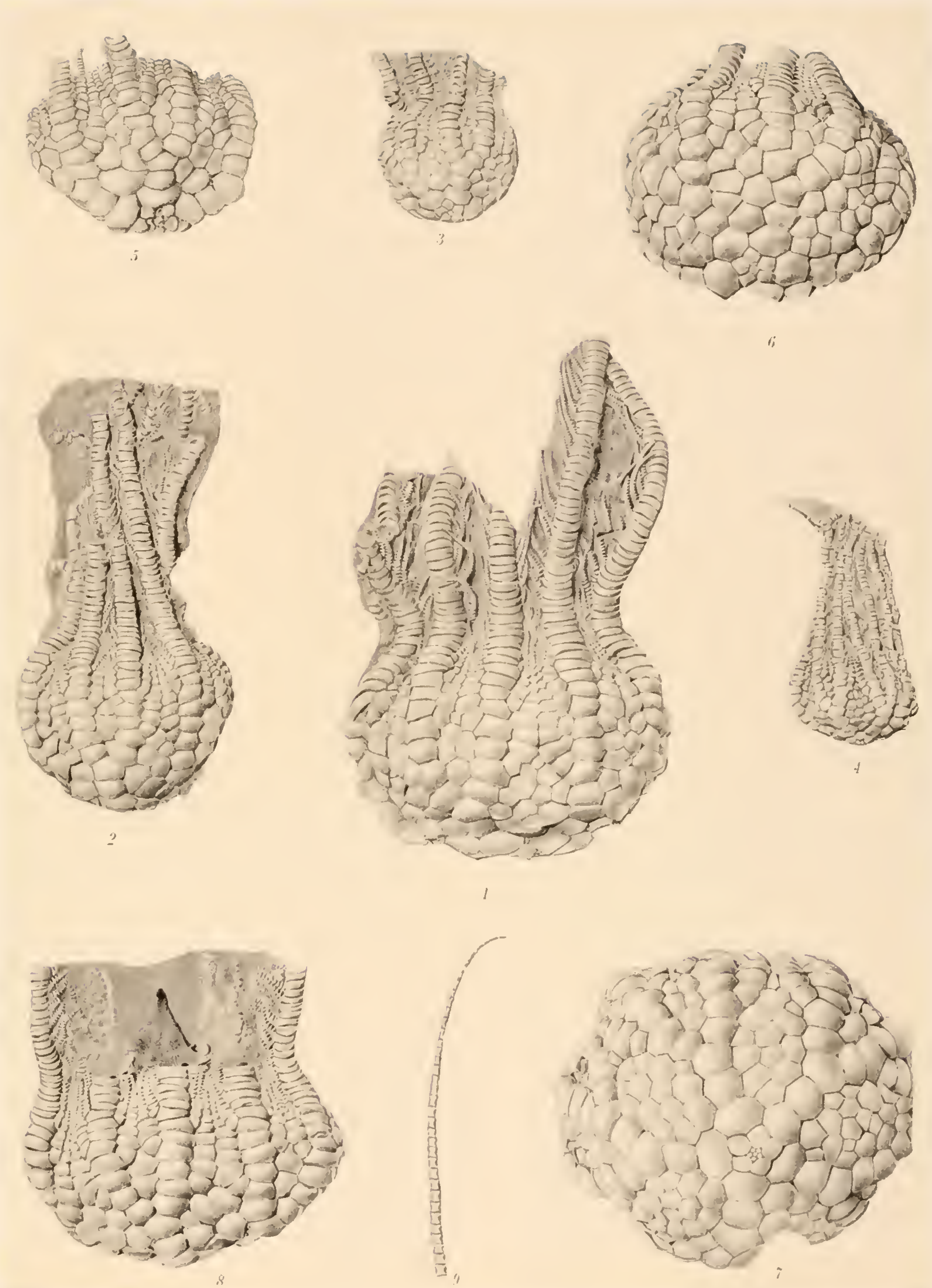
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PLATE VI.

UINTACRINUS SOCIALIS. INTERBRACHIAL AREAS AND IRREGULARITIES.

(Interbrachials indicated by shade lines right to left downwards; intersecundibrachs, left to right; interpinnulars, vertical.)

Fig. 1. Maximum specimen, dicyclic; with 5 iBr plates in one area, and 8, without any enclosed plate, in another. Specimen No. 43.

" 2. Large specimen, dicyclic; with 17 and 20 plates in iBr areas, and 3 plates in lowest range; interpinnulars extensively developed. No. 53.

" 3. Medium specimen, dicyclic; with IBB unequally developed; 6 and 7 plates in iBr areas. No. XXXVI *a*.

(Enlarged figure of base of this specimen: Pl. II., Fig. 8, *supra*.)

" 4. Small specimen, monocyclic; with 5 and 6 plates in iBr areas, showing increase by intercalation in the middle. Collection Kansas University.

" 5. Large specimen with double centrale and one infrabasal; plates of iBr areas varying from 9, without any enclosed plate, to 22, with several enclosed; 2 to 3 plates in lowest range; one iBr passing down between two radials and meeting truncated basal. (The same thing occurs in a perfectly dicyclic and a monocyclic specimen, Nos. LXVI *a* and *b*.) Interpinnulars present. No. 52 *a*.

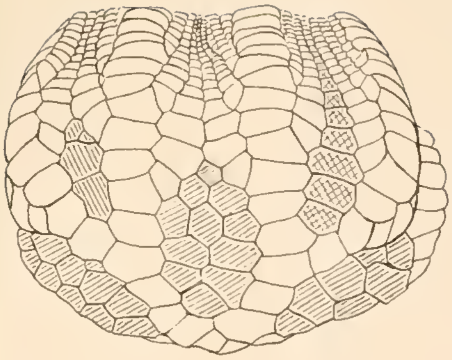
" 6. Large specimen, monocyclic; with 10 to 23 plates in iBr areas; 2 to 3 plates in lowest range; iBr in 3 areas passing down between radials and truncating 3 basals. No. 61.

" 7. Large specimen; the intersecundibrachs in one ray replaced by a large fixed pinnule, indicated by crossed lines. No. 1.

" 8. Medium specimen, monocyclic; the iIIBr plates and one arm branch wanting in one ray, — a large pinnule, marked by a dotted line, originating upon one bifurcating face of IBr_2. Part of No. XIV *c*.

" 9. Large specimen, with an extra pinnule-bearing arm developed in place of the second fixed pinnule of the left ramus of the ray, — indicated by dotted line. Part of No. X *e*.

(All figures natural size. Figs. 8 and 9 by Mrs. Ricker; 4 by Mr. Syd. Prentice; the others by Chapman.)



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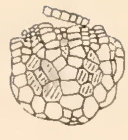

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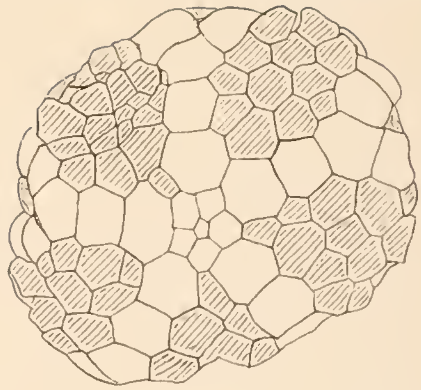

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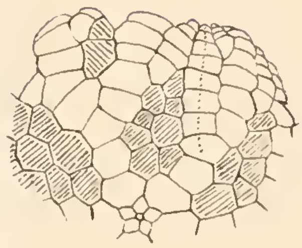

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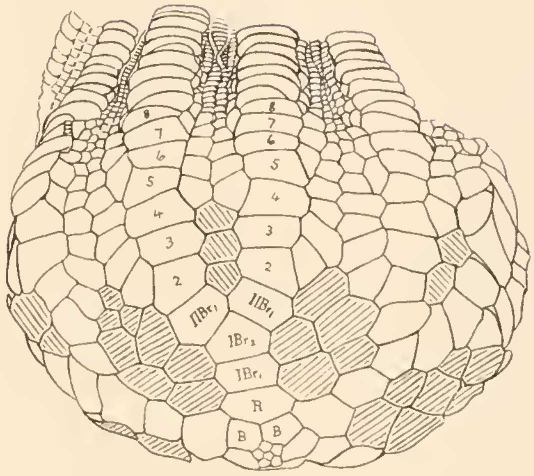

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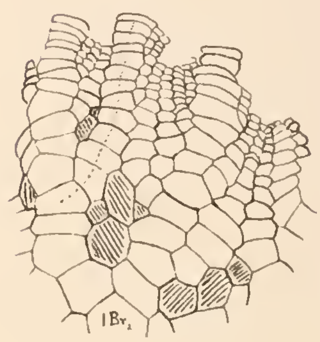

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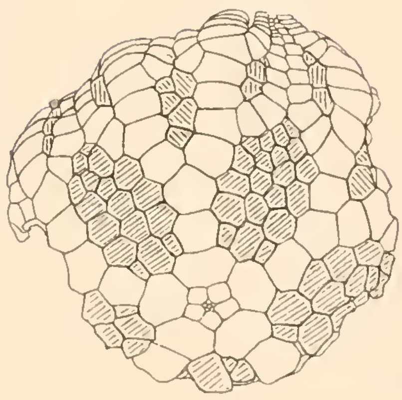

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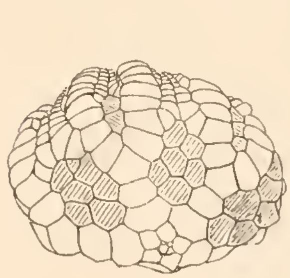

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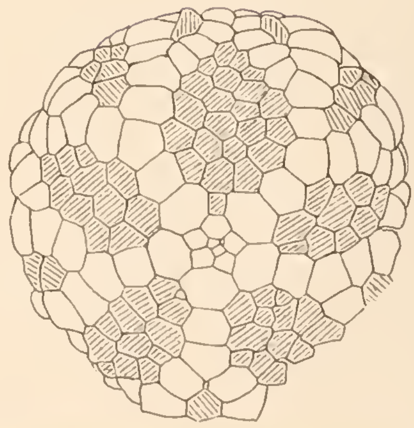

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PLATE VII.

Uintacrinus socialis. Photographs Direct from the Specimens.

Fig. 1. The disk of specimen No. 75 (Pl. IV., Fig. 1, *supra*) enlarged 2.2 diameters by the camera.

" 2. Part of the same disk, enlarged × 10, showing the porous nature of the calcareous spicules.

" 3. Base of specimen No. 247 (Pl. V., Fig. 5, *supra*) enlarged × 2.2; showing the infrabasals lying completely separated from each other and from the centrale.

" 4. Portion of arms and pinnules from specimen No. 233, natural size; to show the relative proportions of brachials in different parts of arms, or in arms of individuals in different stages of growth. The two large arms are from the same calyx, beginning about the 25th IIIBr. The other five, of various sizes, belong to as many different individuals; the smallest one, lying upon the upper part of the left large arm and down along side it, being almost at the distal end. In this figure the dimensions of the brachials in these arms can be compared.

" 5. Detail of same specimen, enlarged × 2.2, to show the form and proportions of the proximal free pinnules, especially the lateral sloping of the pinnulars.

" 6. Disk of specimen No. 205, crossed and obscured by arms and pinnules of other individuals, enlarged × 2.2; to show the form and proportions of the slender pinnulars in the upper part of the arm. Here they are cemented by pressure to the black disk, and by reason of the contrast in color can be well seen.

" 7. Ventral side of arm and pinnules, enlarged × 2.2.

" 8. Articulating surfaces of brachials, enlarged × 2.2; to show the diagonal direction of the fulcral ridges.

" 9. Syzygial surfaces of brachials, enlarged × 2.2, from arms broken off before fossilization.

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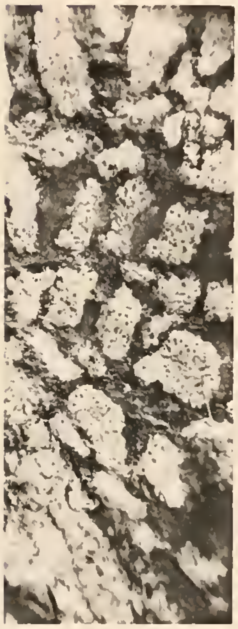

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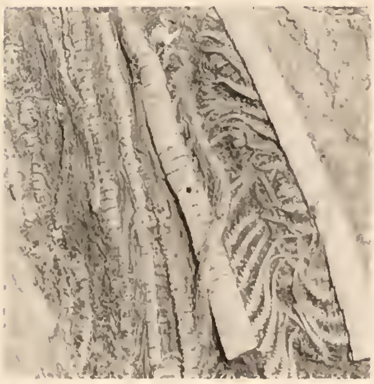

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Heliotype Co, Boston.

PLATE VIII.

UINTACRINUS SOCIALIS. DETAIL OF SLAB I, PHOTOGRAPHED ABOUT .58 NATURAL SIZE. THE DIFFERENT SPECIMENS MAY BE LOCATED BY REFERENCE TO THE MARGINAL LETTERS AND FIGURES.

A 3 and A 5. At these points may be seen some very slender pinnules from almost the distal end of arms, adhering to calyx plates of the specimens on which they lie.

At these points also are seen parts of arms of a large specimen preserved to a length of 60 cm.

B 1. Large dicyclic specimen, with small but perfectly developed infrabasals.

B 7. Ventral side of outspread arms and pinnules, belonging to a calyx almost entirely embedded in the slab; the distal end of the anal tube is visible, but hard to distinguish on the photograph, being so near the color of the adjacent material.

C 3. Specimen with disk exposed. The anal tube is flattened upon itself into a rather shapeless mass which does not show well in the photograph. The ambulacra may be indistinctly seen. The arms are spread, exposing the ventral side of both arms and pinnules with absolute perfection.

C 4. A monocyclic specimen, giving a fine view of the dorsal side of arms, and fixed and lower free pinnules.

D 2. This specimen also gives an excellent dorsal view of the fixed and proximal free pinnules.

(In the last four specimens the pinnules can be seen and studied in almost every conceivable position and exposure.)

D 4. Large monocyclic specimen. Both this and B 1 exhibit a great multiplication of interbrachial plates.

D 6. Small specimen with indistinct base, but showing the arms unusually well. By comparison of the brachials of this specimen and those of C 4, D 2, and D 4, the relative size and proportions of these plates in specimens of various stages of growth may be thoroughly studied.

A B C D

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PUBLICATIONS

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT HARVARD COLLEGE.

There have been published of the BULLETINS Vols. I. to XXXV.; of the MEMOIRS, Vols. I. to XXIV.

Vols. XXXVI., XXXVII., and XXXVIII. of the BULLETIN, and Vols. XXV., XXVI., and XXVII. of the MEMOIRS, are now in course of publication.

A price list of the publications of the Museum will be sent on application to the Librarian of the Museum of Comparative Zoölogy, Cambridge, Mass.